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A TEXT BOOK

OF

BUILDING CONSTRUCTION

[WITH NUMEROUS ILLUSTRATIONS, AND PROBLEMS ON THE STANDARD METHODS OF BUILDING PRACTICE]

A TEXT BOOK
OF
Building Construction

(With numerous illustrations and solved problems on the standard methods of building practice)

By

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Foreword

Indian authors have only recently come forward in publishing Engineering Books to suit Indian conditions for the use of students and practising engineers. Shri Kulkarni has produced an excellent book on Building Construction, right from foundations to roofs.

The book is written in a clear style and studded with over 600 illustrations. It is hoped that students and practising engineers will find it useful both as a text and as a reference book.

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22nd Sept. 1950.

Preface

(To the first edition)

The book is written to serve as a text and reference book to students of Engineering and to those engaged on construction works. It is specially intended to serve the needs of graduates fresh from Engineering Colleges who have to face the duplicate problem of preparing self-explanatory drawings and sketches for use on works and also of executing the works themselves.

With these aims in view, the respective details of construction are explained from the foundation to the roof and final finishing. In arranging the chapters, the sequence of construction is also maintained, as far as possible. As a result of extensive practical experience on varied engineering works for several years and teaching experience to the students of the Engineering College, Poona, the author experience that this method of approaching the subject is very helpful.

The use of numerous illustrations and solved problems further help to impart the fundamentals of constructions to a beginner in the subject. These illustrations form a special feature of the text.

Hubli
1-6-1948

G. J. Kulkarni

A Note on Second Edition

In this edition the chapters on foundations are revised and enlarged. Two more chapters are added on heat insulation and sound insulation to complete the aspects on building construction.

The author takes this opportunity of expressing his great satisfaction for the appreciation the first edition of this book received at the hands of students and practicing engineers alike. It is hoped that the second edition will also continue to serve them to their satisfaction.

Ahmedabad
1-6-52

G. J. Kulkarni.

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BUILDING CONSTRUCTION

A Text-Book of

BUILDING CONSTRUCTION

CHAPTER I

Foundation Soils

FOUNDATIONS:-- Their meaning & purpose. Loads on structures and bearing power of soils. Safe compressive stresses. Priliminary investigations and examination of ground. Testing bearing power of soils. Precautions to prevent uneven settlement and foundation failures.

Art. 1. Foundations—Their Meaning and Purpose. Foundation is the term applied to the base or the lowest part of a structure. It rests directly on the solid ground below, or it is supported by side friction, or by both. This solid ground is specially prepared for the purpose of receiving the load of the structure and is called the Foundation Bed. The entire load of the structure is transferred to the soil through the agency of good foundations, which are essential for the stability and durability of that structure.

Though it is often understood that foundation supports the weight of a structure, it may be said that foundation is a device provided at the base of a structure to transmit the load to the soil on which it rests. In the following pages are enumerated the various conditions to be satisfied before a proper foundation is designed for a structure.

Art. 2. Loads on Structures and Bearing Power of Soils—Before any method of providing foundation to a structure could be specified, the following data is quite essential :—

(a) A detailed analysis of loads acting on various parts of the structure, such as on walls, on columns, etc. should be made with a view to obtain the final load to be transmitted to the soil below, and the intensity of this load per sq. ft.

(b) An examination of the nature and type of the soil for determining its bearing power or its capacity to withstand the load of structure, mentioned in (a) above, after it is built on it.

Table No. I. Deadloads.

Weights of common materials and built-up parts.

No.	Description	Weight
	(A)	lbs./cu. ft.
1.	Broken stone metal	100
2.	Dry Sand	90
3.	Cement	94
4.	Timber	50
5.	Steel	480
6.	Earth filling (dry)	100
	(B)	lbs./cu. ft.
1.	Plain concrete	120
2.	Reinforced concrete	144
3.	Stone masonry	155
4.	Brick masonry	125
	(C)	lbs. /sq. ft.
1.	Plaster $\frac{1}{2}$ in. thick	5
2.	Floor finish $1\frac{1}{2}$ in. thick	12 to 18
3.	Teak wood door	8
4.	Teak wood window	6
5.	Clay tiles including battens ...	15
6.	C. I. sheeting with fixtures ...	2 to 3

When the above two factors are ascertained, a suitable foundation could be designed and constructed in one of the methods explained later.

Art. 3. Loads on Structure—The loads coming upon the foundations are commonly classified into three types:—(i) Dead loads; (ii) Live loads; and (iii) Wind loads.

(i) *Dead Loads*–These are static loads due to the weight of the respective structural members. Permanent fixtures to these members are also treated as dead loads. In table No. I on page 2 are given the values of dead load.

(ii) *Live Loads*–These are incidental loads due to materials stored temporarily on the floors or due to people occupying the floors. Their equivalent dead load values are taken into account. The various live loads are given in the following table No. II as equivalent dead load values.

√ *Table No. II. Live loads on Structures.*

No.	Type of Building.	lbs./sq. ft.
1.	Residential buildings	50
2.	Public buildings	80 to 100
3.	Garages	150
4.	Factories, warehouses and stores ...	200 to 300
5.	Flat roofs	30 to 50
6.	Stairs in residential buildings ...	80
7.	Stairs in public buildings ...	100
8.	Balconies	100

In the case of multi-storied buildings, a reduction in live loads specified in table No. II above is recommended at the rate of 10 per cent per floor downwards. No reduction should be made for the top-most floor and also after a value of 50 per cent is reached, i. e., the sixth floor from the top. All the subsequent lower floors will be assumed to transmit only 50 per cent of the live load coming upon them, to the respective supporting members.

(iii) *Wind Loads*–The effect of wind loads on the face of a structure is to cause an uplift on it so as to reduce the pressure on the foundation bed on the windward side and to increase it on the leeward side. This effect of wind pressure gets reduced as the proportion of the depth of the structure in the direction of the wind to its height increases. Usually a horizontal wind—pressure of 20 lbs/sq. ft. of the projected exposed area is taken.

In addition to the shape and proportion of the structure, the other factors which affact the wind pressure upon a structure are the wind velocity and the angle at which the wind strikes a surface.

Table No. III

Safe Compressive Stresses In Masonry and Concrete.

Serial No.	Description	Tons/ sq. ft.
1.	Cement concrete 1:2:4 ...	25
2.	Cement concrete 1:3:6 ...	15
3.	Cement concrete 1:4:8 ...	8
4.	Lime concrete	6
5.	Brickbat concrete 1:2 lime mortar	2 to 3
6.	Broken stone concrete 1:2 lime mortar.	8 to 4
7.	Ashlar masonry	16
8.	Block-in-course	12
9.	Coarsed rubble masonry in lime mortar.	7
10.	1st class brick masonry in cement mortar 1:3 in pillars ...	12
11.	1st class brick masonry in lime mortar in walls	8
12.	Ordinary brick masonry in lime mortar	4

It may be noted that an allowance for the snow load on flat roofs and on roofs with gentle slopes, is made at the rate of 8 to 13 lbs. per sq. ft. for every foot depth of snow. No allowance is made for roofs sloping at 45° or steeper.

Art. 4, Safe Compressive Stresses–The Cumulative effect of the different types of loads mentioned in the previous articles is worked out for each linear foot of wall and for each column or other supporting member of the structure for which the foundation has to be provided; and it is seen that a sufficient thickness or section is provided for the supporting member so that the material used for its construction is not stressed beyond its safe compressive stress. In table

No. III on page 4, are given the safe compressive stresses in concrete and masonry which are the most common materials used for foundation work.

Art. 5. Types and Bearing Power of Soils—Having considered the different types of loads on structure to be transmitted to the soil below, we shall now investigate the nature and type of the soil with respect to its ability to receive and withstand this load. Because the stability of a structure depends upon this.

The materials on which a structure ultimately rests may be broadly classified into Rocks and Soils. Solid rock masses are usually satisfactory and provide sounds foundation beds for structures to rest upon. The conditions in which soils occur are principally of two types, those overlying a hardpan with increasing stiffness-and strength, and those that are generally loose and extend over a considerable depth as in the case of alluvial track, sandy regions and estuaries. Soils generally occur as (i) clayey soils, (ii) sand and gravel, (iii) a mixture of clayey and sandy soils with or without gravel and pebbles. Some clayey soils are treacherous as they expand and contract considerably when wet and when dry. Rock beds are not always available and the engineers have to design foundation on anything varying from clayey soils, sand beds, hard murum, to soft rock. Each soil has its own bearing power or capacity to receive and withstand loads, which is determined by one of the methods mentioned in the following articles.

It should be remembered that the same soil if confined, will have a greater capacity to sustain loads than when free to squeeze out under loads; and this condition is fairly reached if the soil lies at greater depths. Sometimes sheet piling is driven to enclose the soil and to produce the same effect artificially.

The bearing power of a soil is expressed in terms of tons per sq. ft. and is the basis of all the calculations for design of foundations for a structure. The intensity of load coming

(b) *Open Excavation Pits*—Where foundations are not deep, trial pits are excavated to investigate the actual conditions below the ground level. The size of the pit depends on its depth. If the soil is soft and sides of excavation do not stand a vertical cutting, supports of timber planks will be required to prevent the earth from falling in. Excavation should be carried slightly deeper than the proposed foundation bed.

(c) *Probing*—In soft soils like clay, sand, and gravel, a steel crowbar of 1 to $1\frac{1}{2}$ in. diam. with a pointed end is driven to a suitabe depth, either by allowing it to fall under its own weight or by means of a hammer. The amount of force required to thrust the crowbar into the ground is taken as a rough index to determine the type of soil and its compressibility. Occasionally the crowbar is drawn out and the particles of soil sticking to its point are examined. This is however a rough method and is not suitable for deep holes.

(d) *Use of Post-Hole Auger*—For shallow foundations Post-hole augers with lengthening bars are used upto a depth of about 6 to 8 ft. At the top there is a lever arrangement to rotate the auger for driving. Samples of the soil are taken and thier examination is made. Sometimes the auger is placed inside a casing pipe for more accurate work. With an encased pipe deeper borings could be taken, and in clay sand borings upto 50 ft. are possible.

Art. 7. Examination of Ground (*Contd*)—The examination of the conditions of the subsoil for foundations of heavy structures, as in the case of tall buildings, towers, reservoirs, dams, and bridges, etc. has to be made in an accurate and systematic manner. The following three methods are employed for the purpose.

(e) *Percussion Borings*–When the strata is compact and hard a jet of water is used to help the driving of the pipe for taking borings. The steel pipe used for the purpose is hollow and has a diam. of 2″ to 4″ and is known as the

casing pipe or the drive pipe. It is driven into the soil with the help of blows delived from an eccentric disc of a percussion boring machine. For every revolution of the disc the steel pipe is raised and allowed to drop down. Thus the cutting edge provided at the end of the pipe breaks up and pulvarises the hard soil below. The soil is softened in this manner in front of the cutting edge. Inside the casing pipe is a wash pipe of about 1 inch. diam. and extends to the bottom of the casing pipe. Through this pipe, water is forced downwards, and is allowed to rise up in the annular space between the wash pipe and the casing pipe. The pulvarised material is thus washed and brought upto the surface under pressure, and is then examined and tabulated for a detailed study and interpretation.

(f) *Wash Borings*—If the soil is soft like clay and sand, the boring can be done by forcing the drive pipe with the aid of only a hydraulic jet under pressure. This gives a fairly good idea of the character of the soil but does not give the exact position of the soil in the formation or strata.

(g) *Core Boring*—For studying the subsoil rock conditions and specially when large boulder are encountered, a more complicated method of taking drills by a core drilling machine is adopted. The machine consist of a hollow rotary pipe with a cutting bit and steel balls. These make an annular cut in the rock by the abrasive action due to rotation and consequent grinding. A cylindrical core of $1\frac{1}{2}$ in. diameter is thus cut out of the rock mass and is removed to the surface for examination.

(h) *Test Cylinders*—In the case of heavy foundation for bridges, etc., and when the soil consists of clayey and sandy formations extending over great depths, iron cylinders of diam. varying from 3 to 5 ft. open at top and bottom, are driven. Samples of soil are taken out and examined. Subsequently these cylinders are sealed up from inside and are loaded from top for testing the bearing power of the soil also.

The various testing methods enumerated above should be carried out in a reasonable number of spots over the entire site. The results of all such tests should be properly recorded in log-books and carefully studied before any type of foundation is specified for a structure. It should be remembered that water causes the greatest trouble in all foundation work, particularly with porous soils. To exclude this water and also to lower down the ground water level, heavy pumping has to be resorted to. Ground water also alters the structural properties of soils which results in damages to foundations by uneven settlements and cracks by irregular tension.

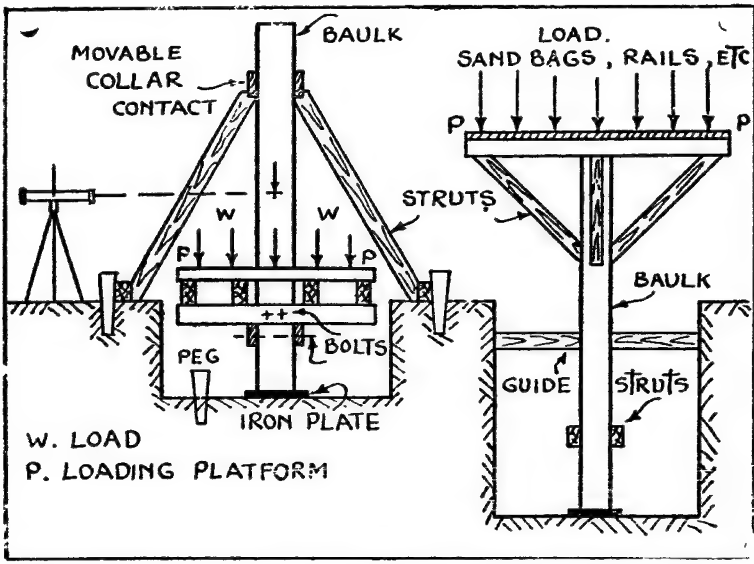
On large works where the foundation problems are very often complicated and present different aspects, as in the case of those for bridges, dams and tunnels, preliminary investigations should also include a geological report about the soils and their formations at the site, at the hands of expert geologists.

Art. 8. Testing Bearing Power of Soils—Normally investigations are carried out by the respective town and city authorities for determining the nature of the soils and their bearing powers within their town limits. The results of these investigations are expressed in the form of regulations in their building codes. The foundations of all buildings designed within these limits have to comply with such regulations.

The following methods are used for determing the bearing power of any desired type of soil. But for important buildings and in places where such regulations do not exist, bearing powers are determined by actual load tests on soils. There are different methods of applying loads to the soils.

(i) *Methods of Loading the Soils–First Method*—One of the methods in its simplest form consists of a timber vertical baulk 10″ to 12″ square and 6 to 8 feet long placed in a trench excavated for the purpose. The excavation is

carried to the firm soil on which the structure is to rest and whose safe bearing power is required. An iron plate of a size slightly bigger than the section of the baulk is placed at its foot (See. Fig. 1). On top of the baulk a suitable platform P is provided to support the load to be transmitted to the soil. Horizontal cross struts or guide struts are provided in the trench for the lateral support of the baulk and also to act as guides, as it sinks under loads. The

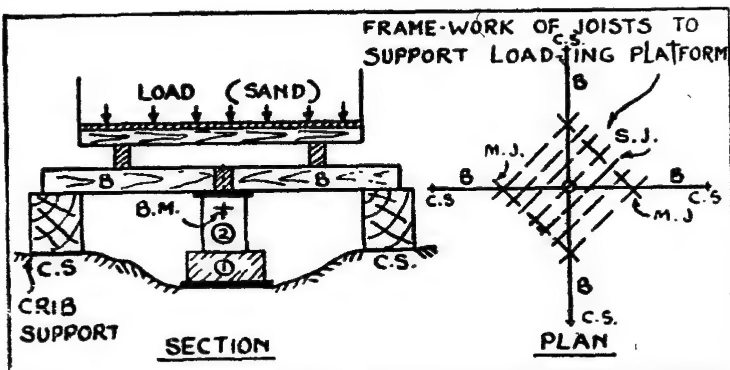


Figs. 1 and 2. Different methods of loading a soil for its bearing power.

contact between these struts and the baulk is kept well greased to facilitate easy sliding. The test load is applied gradually and symmetrically and usually consists of sand or earth bags, bricks, old rails, pig iron, etc., of known weight W. The desired load can also be applied by means of a hydraulic jacks with a pressure gauge. Anchor blocks have to be provided to take up the reactions of the jacks.

(ii) *Second Method*—In Fig. 2 is illustrated another method of applying test load to soils. If the trench is shallow or the bearing power of the soil is high, guys or inclined struts are provided to facilitate the sinking of the baulk

in the vertical position. A movable collar contact is made between the baulk and the inclined struts. The platform P carrying the load W is fixed rigidly to the baulk with the aid of four bolts at right angles as shown. To ascertain the corresponding sinking of the baulk at each stage a level is planted nearby for taking readings, A permanent bench mark is made nearby with respect to which all readings are taken. A couple of pegs may also be driven in the trench and readings taken on these pegs to watch the settlement, if any that has taken in the adjacent ground surface.



Figs. 3 Another method of loading a Soil for ascertaining its bearing - power.

Fig. 4. Plan of loading platform.

(iii) *Third Method*–In the third method of loading soils to ascertain their bearing power, an arrangement shown in Figs, 3 & 4 is made. Four independent beams B are placed with their one end on four separate timber crib supports marked C. S. and their other ends are brought to-gether and are made to rest on a single central support marked (1) and (2). The support (1) has an approximate contact area of four squre feet with the ground. Iron plates should be used at top and at bottom of the central support for proper distribution of loads to the soil.

The loading platform is supported on a frame-work of joists as shown in plan. Two main joists M. J. are placed

directly over the beams B and the secondary joists S. J. are placed over them. Thus the load coming on the soil is only half of the total weight on the platform, if the main joists, rest on centre points of B. At free ends of the loading platform, suitable bolts and jacks should be provided to prevent its tilting, and also to effect a balanced loading.

Art. 9. Remarks on Test for the Bearing Power of Soils—If it is intended to carry out a conformatory test to determine whether the expected safe bearing power of a known soil could be safely relied upon, the following procedure is recommended. A test load of the value of about 4 to 5 times the expected safe bearing power of the soil is placed on the platform and settlements of the baulk are observed every day at a fixed hour, until no settlement occurs in 24 hours. See part A in the table No. V of results. Then the test load is increased by about 50 percent and obeservations are made every day until again no settlement occurs in 24 hours. See part B in the same table. In both the cases, the total settlement should not exceed about 2/3rd of an inch and 1 inch respectively. A method of recording results is shown in Table No. V on page 14.

While drawing conclusions about the bearing power of a soil, based on the above experiments, the following points should be noted:—

(i) That the values of the results are greatly affected by the manner of loading, which should be done gradually without giving shocks to the loading platform.

(ii) That small area will bear a larger load per unit of area for a short time than what a larger area can bear perpetually.

(iii) That the area of contact of the soil with the load should be as large as possible.

(iv) That three to four different sizes of plates should be used for loading and an avarage value should be taken. This makes due considerations for the experimental results

Table No. V.

Bearing Power Of Soils–Record Of Results Of Testing.

Note–**Type Of Soil : Compact Clay, Dry.**

Serial No.	Date. time	Test load	Increa-ments in settle-ment	Total Settle-ment	Remarks.
Part A	10. 00 A. M.	Tons. Cwts.	inch	inch	Loading completed,
1.	12.0	7—12	0.21	0.21	
2.	13.0	-do-	0.10	0.31	
3.	14.0	-do-	0.04	0.35	
4.	15.0	-do-	0.02	0.37	
5.	16.0	-do-	0.01	0.38	No settle-ment.
6.	17.0	-do-	0.00	0.38	
Part B					
1.	18.0	11-6	0.15	0.53	Loading completed.
2.	19.0	-do-	0.03	0.56	
3.	20.0	-do-	0.03	0.59	
4.	21.0	-do-	0.01	0.60	
5.	22.0	-do-	0.00	0.60	No settle-ment.
6.	23.0	-do-	0.00	0.60	

since the bigger plates have a proportionately lesser total shear resistance at their perimeter due to smaller perimeter-area-ratio. If x is the direct normal pressure of the soil and y is its perimeter shear, then the bearing power of the soil is given by :—

$$p = x + y\frac{P}{A};\qquad \begin{array}{l} P = \text{Perimeter of plate.} \\ A = \text{Area of plate.} \end{array}$$

The values of x and y are determined by a minimum of two values of loads Ap for an equal settlement.

(v) That the tests should be continued for as long a

period as possible. Usually it takes 3 to 5 days for a soil to adjust itself to the load placed upon it.

To determine ultimate bearing power of the soil, loads are applied to the platform as mentioned in the previous methods, in suitable increments which are usually $\frac{1}{2}$ ton. The load is allowed to stand after each increament until settlement ceases. The recording should be done in a manner shown in table No. V. Usually a maximum settlement of $1\frac{1}{4}''$ to $2''$ is reached. The results of loads with their corresponding values of settlments are plotted graphically and the value of the load which causes the curve to suddenly bend down is ascertained. A factor of safety of 3 to 4 is applied to the ultimate bearing power as determined above and the safe or allowable bearing power on the soil is estimated. If the foundation area is great as in the case of heavy structures, a lower factor of safety could be used. But if the foundation area is less and if there is a good deal of live load and loads causing impact are acting, a higher factor of safety should be adopted to have a lower value for the safe bearing power for the soil.

Art. 10. Precautions to Prevent Uneven Settlement and Foundation Failures—Uneven settlement of foundations is dangerous in as much as it causes cracks in buildings, which in the long run bring about their failure. If these cracks occur on the external faces, in bathrooms, lavatory blocks, roofs, etc., moisture gains access into the body of the building, sets up decay and causes distruction. This is prevented in the following ways:—

(a) Great care should be exercised to adopt a suitable value for the allowable pressure on the soil giving due consideration to the magnitude and nature of the loads coming upon it and to the effects of the subsoil water conditions have on bearing power of the soil.

(b) Much also depends upon the choice of right type of foundation design to be adopted in each case.

(c) A sufficient base area should be provided below walls and columns so that the intensity of pressure at the base does not exceed the safe bearing power of the soil.

(d) The intensity of pressure at the base of a structure where it comes in contact with the foundation bed should be uniform and the same for any one structure.

(e) Foundations for a structure should be taken sufficiently deep below the decaying surface layer of earth, so as to reach a subsoil which is uniform and homogeneous and possesses the necessary bearing power.

(f) The bearing power of the soil should not be affected in the course of time by the changing atmospheric conditions and by the presence of the sub-soil water. Black soil requires special mention for its behaviour when wet and when dry. This soil becomes slushy when wet and thereby greatly loses its bearing power. When dry vertical cracks are formed resulting in a lateral movement in the soil. This introduces tensile stresses in foundations and causes lateral movement in the different parts of the base of the structure.

As a precautionary measure, the excavation for foundation should be taken deep beyond the reach of these cracks and the materials used for foundation work should be capable of taking the tensile stresses. R. C. C. foundations or the driving of piles upto the hard pan or rock are recommended. It is also necessary to introduce a layer of loose material such as rubble and coarse sand between the foundation and the clayey soil to prevent the structure and the treacherous soil from coming in contact with each other.

(g) The line of action of the resultant load of the structure should be concentric with the area of the foundation base on which it stands. This results in an even distribution of load on the foundation bed. Any eccentricity between the above load and the resultant of the soil reaction causes an overturning couple and an uneven distribution of pressure at the base.

(i) The materials used for the foundation work should not be such as would deteriorate or disintegrate in the course of time due to atmospheric action. Stone masonry and concrete, either of lime or of cement, are invariably used for work below ground level and up to the plinth. If any material which is liable to deterioration is used, it should be properly protected to increase its durability.

(j) No disturbance of the foundation bed should be permitted under any circumstances, by careless adjoining excavations either for the construction of new building or

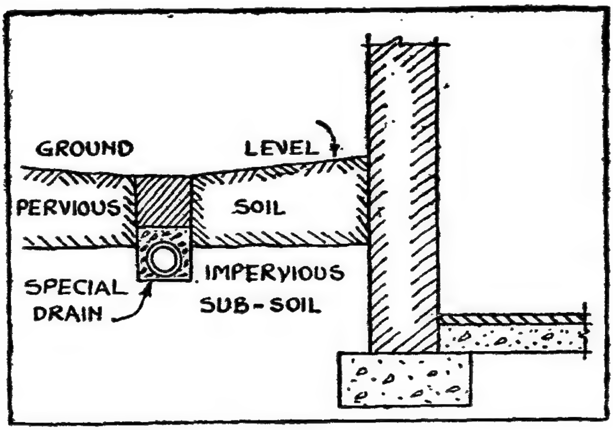


Fig. 5. Drainage of foundation.

for the laying of pipe lines, etc. Such an excavation induces lateral escape of soft materials like loose sand, clay, etc. from underneath the foundation, and causes settlement.

(k) The ground round about a structure should be kept free from underground water troubles, particularly when there is a basement to a building. Permanent water troubles and those due to the soaking of surface water could be avoided by sloping the ground surface away from the building and also by constructing special drains as shown in Fig. 5. Another effective method of deep subsoil drainage is illustrated in Fig. 6.

(l) The filling of the sides of trenches after foundation is laid should not be done in a slip-shod manner; Fig. 7. indicates the method of filling in the foundation trenches in horizontal layers under dry conditions and when there is no water trouble.

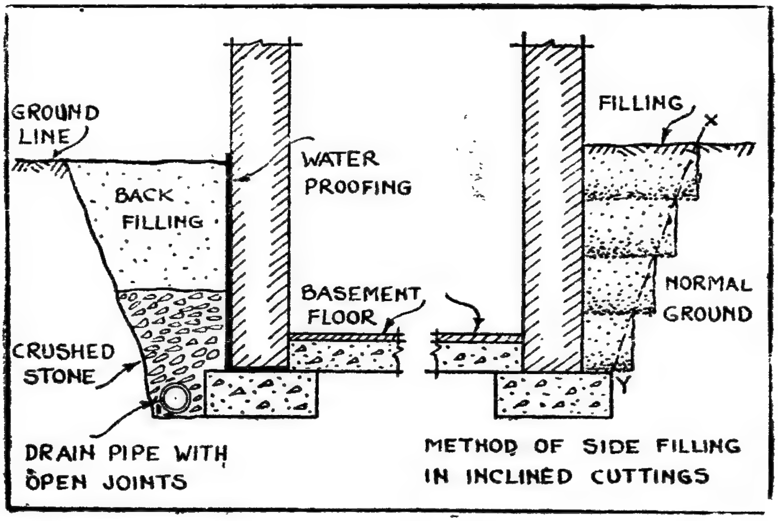


Fig. 6. Drainage of foundation. Fig. 7. Soil filling in inclined cutting.

Art. 11. Improving Bearing Power of Soils—In some cases it will be found necessry to improve the bearing power of the soils for strengthening the foundation beds. The following are some of the methods commonly used :—

(i) Cheap materials like rubble, broken stone, gravel or sand are forced into the soil by ramming. A conical weight is dropped to form a depression on the surface and the above materials are filled in and well rammed.

(ii) By driving short timber piles or concrete piles and mechaically compacting the soil, its bearing power also can be increased.

(iii) Another method is to confine the soil in an enclosed area with the aid of sheet plies. This process in known as cupping and is very effective.

(iv) The soil can also be hardened by the cementation process, by which a grout of cement or cement and clay is pumped under pressure into the pores of the soil. The pores are thus sealed up. To ensure a proper distribution of the cement grout, the ground is drilled and perforated pipes are introduced to force the liquid. In some cases pressures as high as one ton per sq. in. are used for deep soil impregnation. Special chemical solutions are also used in place of cement grout. Cement and the chemicals set in course of time and harden the soil which can thus take a proportionately greater load from spread footings. Emulsions of bituminous materials are also used for soil injections and for soil stabilisation. They keep away water from any part of the soil by virtue of their waterproof qualities.

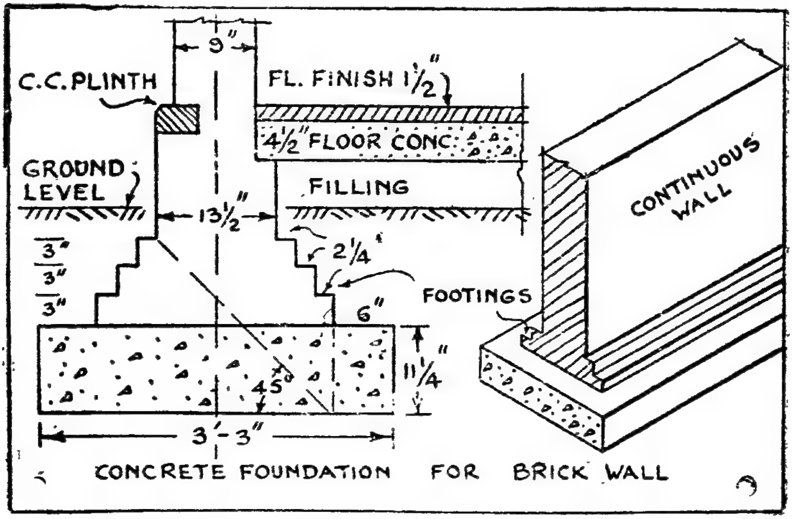
CHAPTER II

Spread Footings and Raft Foundations

Methods of providing foundations to structures. Spread footings for walls and columns, Grillage. foundations, R. C. C. spread footings. Combined footings. Cantilever spread footings. Failures of spread footings. Raft foundation,

Art. 12. Methods of Providing Foundations to Structures—Principally there are four methods of providing foundations,

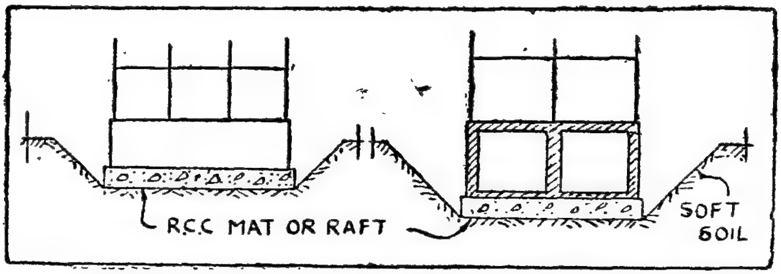
(i) Spread footing; (ii) Raft foundations;
(iii) Pile foundations; (iv) Cylinders, caissons, piers and wells.



Figs. 8 and 9. Spread footings for walls.

(i) *Spread Footings* in general include all methods of widening the base of a structure to suit the bearing power of soils on which they rest. Each column and wall have independent footings. See figs. 8 and 9. But if the bearing power of the soil varies or alters due to change in subsoil condition under any footing, uneven settlements will occur in different parts of the same building, and cause foundation failures.

(ii) *Raft or Mat Foundations* are in the form of continuous slabs covering the entire area of the bottom of a structure, like a raft or a mat. They are often used if the bearing power of the soil is very low and spread footings do not give enough area as these footings either come too close or overlap one another. Rafts and Mats are also used when there is a possibility of uneven settlement to occur. See figs. 10 and 11; fig. 10 when no basement is used and figs. 11 when basement is used. In heavey structures where the intensity of load cannot be reduced by any widening of the base, deep excavations are taken to a harder stratum of soil or to a bed of rock to provide the necessary foundation.



Figs. 10. and 11. Raft foundations.

(iii) *Pile Foundations*, include the method of driving piles of wood, concrete or metal to a depth until their lower end rests upon a rock bed, or their length is enough to offer the necessary frictional resistance to support the structural loads. The base of the structure is then made to rest upon their top. Pile foundations are specially suited for made-up soils as described later.

(iv) *Cylinders, Caissons, Piers and Wells*–When loads of very heavy structures are to rest on rocks or hard strata extending over a considerable depth, as mentional above, special types of foundations have to be provided by sinking steel or R. C. C. cylinders, caisson, and wells or by building piers. For ordinary buildings these are not generally provided. For details see next chapter.

The above methods of laying foundations are described in the foregoing articles.

Art. 13. Spread Footings–Spread footings are of two types, (a) Wall footings; and (b) Column footings.

(a) *Wall Footings*—The nature of loading in walls and columns is intensive and usually exceeds that permissible on soils on which they have to rest. For this purpose, the lower parts of walls and columns are widened out to form footings which rest on a concrete foundation. A Typical spread wall footing is shown in fig. 8. The same foundation is shown in isometric view in fig. 9. It is necessary that the foundation bed is prepared horizontal.

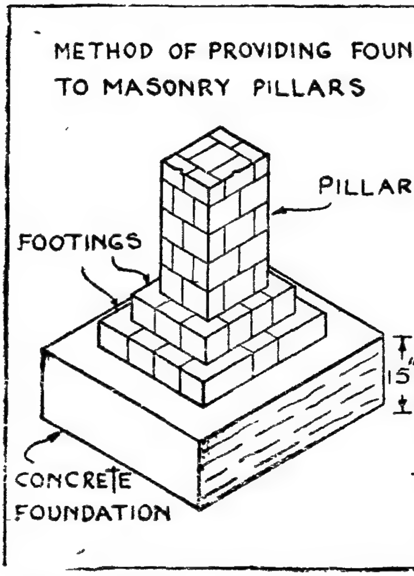
On a sloping ground steps are arranged longitudinally so that the foundation bed is always maintained horizontal by giving a vertical drop at suitable intervals. They follow the general contour of the sloping ground, and the drop-down depth of each step is generally equal to the thickness of concrete but not more than twice this thickness. While providing the steppings care should be taken to see that the foundations are taken deep to anchor the building to the site. If necessary anchor piles should be driven. Otherwise there will be a slip.

The offsets of concrete should be not less than 6 ins. beyond the edges of the lowest footing on either side. To obtain the thickness of concrete required to resist shear stresses, a line is drawn from the face of the wall at an angle of 45 degrees. Brick footings should have an offset of $2\frac{1}{4}$ ins. which is the size of a quarter brick and those of stone masonry 3 ins. Sometimes the lowest footing is built in two courses to increase rigidity at the base. The footings may be built of concrete also, in a stepped fashion similar to masonry ones described above.

Art. 14. (a) **Plank Foundation for Footings**–in soft soils and marshy grounds, concrete base for footings or raft is sometimes replaced by timber sections usually 9″ × 12″

laid in two layers. In the lower layer the pieces are laid crosswise to the wall and in the top layer length-wise. In such cases suitable timber should be available and that it should remain permanently under water and should not be subjected to alternate wet and dry conditions.

(b) **Column Footings:**-*Isolated Foundations to Brick Masonry Pillars* — In fig. 12 are given the details of providing concrete foundations to an isolated masonry pillar.



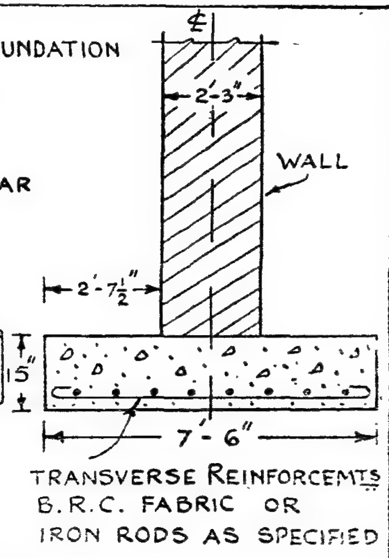


Fig. 12 Method oi providing foundation to masonry pillars.

Fig. 13. Raft foundation for wall.

It will be noted that the footings and the concrete projections are arranged symmetrical on all the four sides to distribute the concentrated load in the pillar, uniformly on the soil below, so that the bearing power of the soil is not exceeded.

Art. 15. Grillage Foundation to Columns—Steel stanchions are provided with independent grillage footings consisting essentially of two tiers of horizontal-rolled steel joists embedded in cement concrete. The arrangement of

the two tiers one over the other at right angles is illustrated in Fig. 14. Lower tier consists of 7 — 10″ × 5″ @ 30 lbs. R. S. Joists and upper tier of 4 – 15″ × 5″ @ 42 lbs. stanchion. A base plate is introduced between the stanchion and the top tier flanges. The sequence of load transmission from the stanchion to the foundation bed is through the base connections, base-plate, upper tier, lower tier and the monolithic concrete mass in which the entire grillage work is embedded. The concrete encasing for the

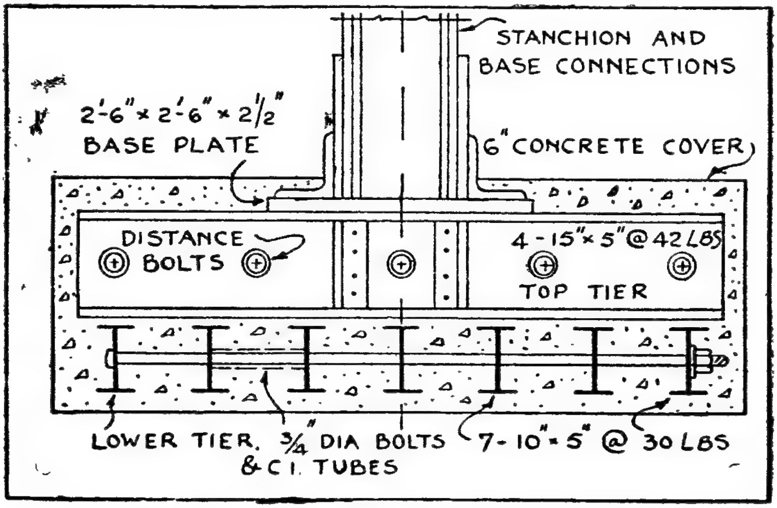


Fig. 14. Grillage Foundation for steel stanchion.

tiers protects the steel from corrosion in addition. Note the use of tube separators with a long iron bolt passing through them to maintain the spacing between the respective R. S. Joists.

Art. 16. R. C. C. Spread Footing for an Isolated R. C. C. Column—R. C. C. Columns are provided with a special type of spread footing as shown in Figs. 15 and 16.

The footing should be sufficiently strong to prevent its failure in the following ways :—

(i) By punching shear between the column and the base of the column.

(ii) By loss of adhesion between the column rods and the concrete in the footing.

(iii) Diagonal shear in the footing concrete.

(iv) Due to bending in the projected portions of the footing beyond the face of the column.

Art. 19. Combined R. C. C. Spread Footings—In Cities often the exterior columns have to be located along the boundary lines of the property. But at the same time it is not permitted to spread the footings beyond the boundary into the adjoining property, equally on all sides of

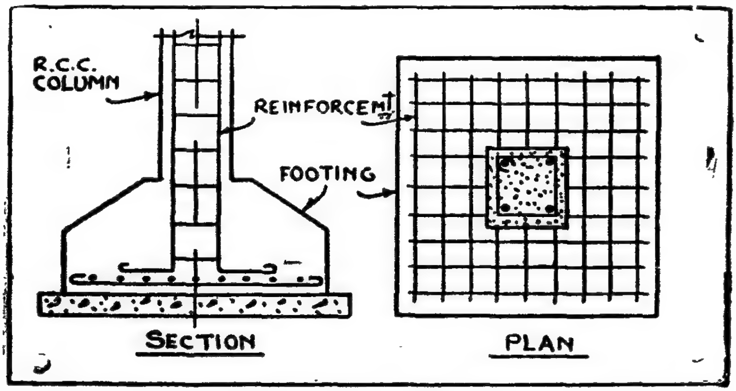


Fig. 15. R. C. C. spread footing for Isolated columns.

Fig. 16. Plan showing reinforcements.

these boundary columns. Consequently one or more of these interior columns are designed to have a common base with the exterior column to form a combined footing. When designing a combined footing, the following points are kept in view :—

(i) The combined base area of the footings should be equal to or more than that obtained by dividing the total load of the column and the footing, by the bearing power of the soil. The shape given to this area is usually rectangular or trapezoidal, as shown in Figs. 17 and 18.

(ii) Whatever may be the shape of the area of the

base, its centre of gravity and the centre of gravity of the combined loads should lie in the same vertical line.

(iii) For columns, the distance between which is great, independant footing is provided for each, and each pair of columns is connected by a footing beam.

(iv) If the combined footing is extended longitudinally beyond the column faces the bending moment in the section between the columns is reduced.

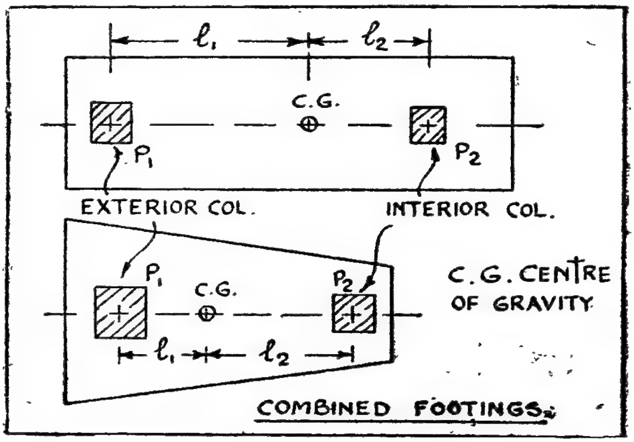


Fig. 17. Combined R. C. C. spread footing, Rectangular type.

Sometimes combined footings are provided between interior columns also and the loads on these columds may be equal or unequal.

Art. 20. Cantilever Spread Footings—When the exterior column mentioned in the previous article has to be taken flush with the boundary line of a property, when building area is restricted, cantilever footings are arranged. The two columns, exterior and the interior, P_2 and P_1 respectively, see Figs. 19 and 20, are provided with independant footings which are connected by a cantilever beam. It will be noticed that for the exterior column an eccentricity of "e" is provided between the load P_2 and the reaction of the soil, whereas the load P_1 and the corres-

ponding reaction of the soil are concentric. The tendency of the exterior load P_2 acting at one end of the cantilever to over turn, is balanced by the whole or a part of the downward pressure of P_1 acting at the other end of it.

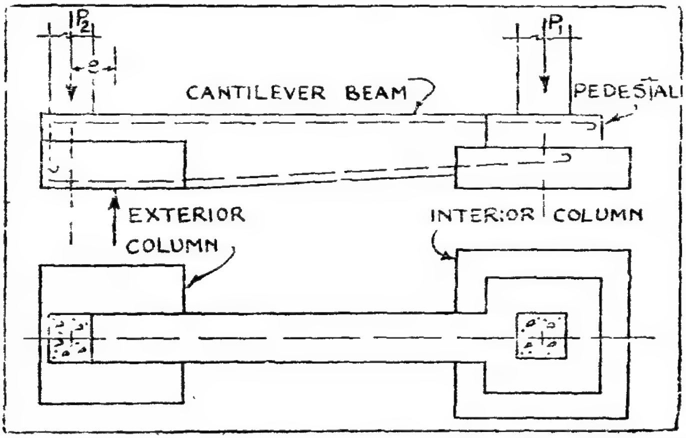


Fig. 19 Centilever spread footings. Fig. 20. Plan of the above.

Cantilever footings may be constructed either of R.C.C. beam and footings, or of steel beam and grillages.

Art. 21. Combined Footings with Grillages and Steel Girders—Rolled steel joists and built-up steel sections

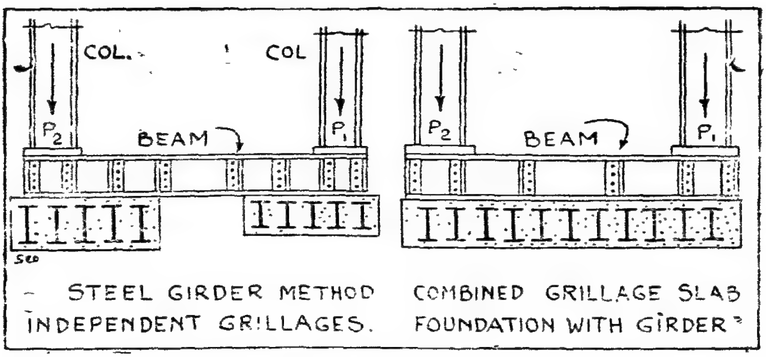


Fig. 21. Independent grillages. Steel girder method.

Fig. 22. Combined slab foundation with girder.

are also employed for providing combined footings to stranchions. The principles of design are similar to those for

R.C.C. combined footings, except that in the case of grillage footings, concrete acts mainly as a casing material and is therefore not fully taken advantage of.

(i) *Steel Girder Method*—Independent grillages. This method is illustrated in Fig. 21. Indepedent grillages are provided to each of the two stanchions carrying loads P_1 and P_2 and they are connected by a steel girder.

(ii) *Combined Grillage Slab with Girder*—See Fig. 22. In soft soils where more footing area is required, a combined grillage slab is designed and the two stanchions are joined by a girder on top.

Art. 22. Raft Foundation—Sometimes a wall rests directly an a concrete base without any footings as shown in Fig. 23. The foundation base is of cement concrete reinforced transversly either with B. R. C. fabric or with iron rods, to take up the bending stresses due to the cantilever action of the projected portions beyond the face of the wall. It should be noted that it is always advantageous to lay a levelling course of a minimum thickness of 3 ins. of 1 : 4 : 8

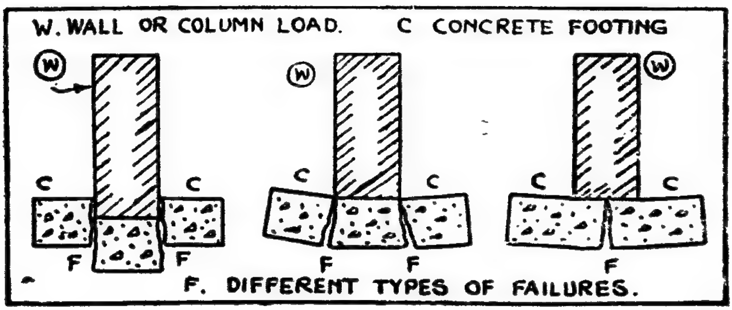


Fig. 23. Failure of footing by shear.

Fig. 24. and 25. Failure of footing by bending or rupture.

cement concrete below all R. C. C. work which comes in contact with the earth in foundation. Floating foundations are the extreme cases of raft foundations or mats when the entire structure rests on a practically monolithic raft or footing. They are suitable in soils of more plastic in nature.

Generally raft foundations and mats are adopted when soils are very weak and the large areas of spread footings for columns and walls make them one another meet. A continuous mat or raft foundation is shown in Figs. 10 and 12. One of the draw-backs of a mat is that it requires to be rigidly connected with the plinth and the upper floors. The basement or the basement and the first floor, are designed as a rigid frame. Secondly for perfect stability, the centre of gravity of the reaction of the soil on the mat must coincide with the centre of gravity of the loads of the structure acting on the mat.

Art. 23. Structural Failures of Spread Footings—Footings are generally found to fail in two ways:—

(i) By Shearing; (ii) By Bending or Rupture; (iii) By Crushing (iv) By Spreading.

(i) Failure of footing by shear, is indicated in Fig. 23. The wall is forced through the base under its own weight and the two projecting sides are thrust in the upward direction.

(ii) Failure of footing by Bending or Rupture. This type of failure is shown in Figs. 24 and 25. It will be noticed that though the central wall portion is stable, the base has failed by bending stresses either at the faces of the wall or directly below at the centre of the wall.

(iii) A footing may also fail by direct crushing of the materials composing the footing under the supported load.

(iv) If there is a lateral movement in the foundation bed, as is usual in the case of clayey soils, failure of footing takes place by spreading. It may be noted that these last two types of failures are very rare.

CHAPTER III

Pile and Well Foundations.

Pile foundations. Wood piles and R. C. C. piles. Pres-cast concrete piles. Pile driving. Bearing power of piles. Different formulae used. Cast-in-situ piles. Simplex, Vibro, Franki, and other piles. Sand piles. Grouping of piles and pile caps. Pier foundation. Steel cylinders. Caisson and well foundations.

Art. 24. Foundations on Piles :—The third method of providing foundations to structures with the aid of piles as stated in Art. 12, will not be considered. Generally pile foundations are used when the ground near the surface is very weak or is of a made–up type and consequently spread footings or rafts could not be provided. When the subsoil water trouble is great, piles are also used. Piles are classified into:—

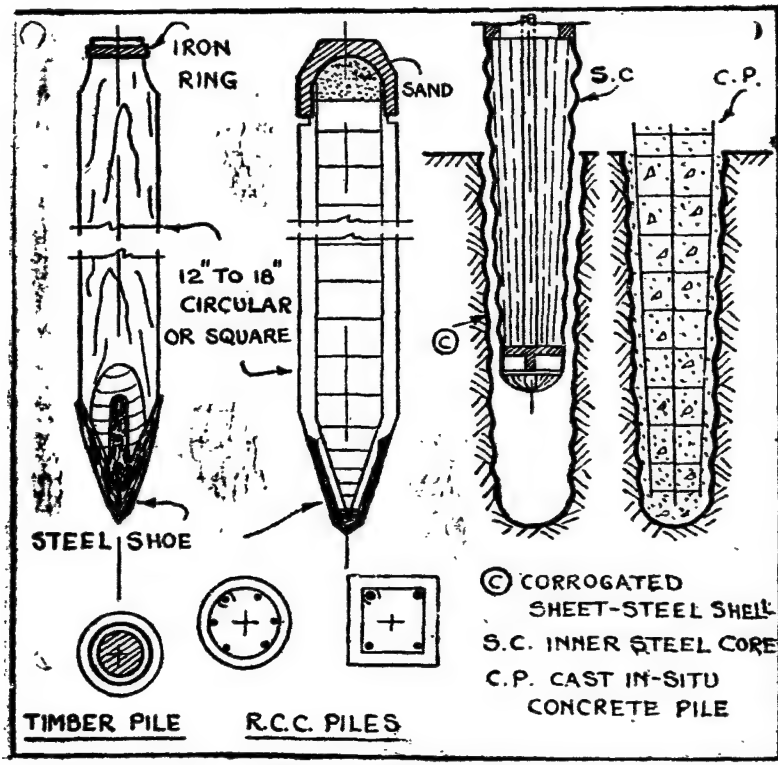
(i) *Bearing Piles*; (ii) *Friction Piles* (iii) *Sheet Piles*. according to the Method in which the load carried by them is transmitted to the soil; and the Functions performed by them. Bearing piles are the usual type of piles which are driven until their ends rest upon rock or hardpan below, to which they transfer the load of the structure vertically. Bearing piles may be of timber or of concrete. Friction piles support the load by the frictional or skin resistance between the surrounding soil and the sides of the pile. The piles in this case, are not driven to hard rock or hard-pan.

Sheet Piles—This class of piles is essentially used during construction of foundations and not as foundation member of a structure. Their main function is to enclose a certain area of the ground within which the foundation laying work could be carried out, and also to confine loose soils to inprove their bearing power.

Depending upon the materials used attempt is also made to classify the piles as :—Wooden piles. Concrete piles,

R. C. C. Piles, Steel piles, Composite piles. Further classification of piles based on the methods of driving them is discussed in the course of this chapter.

Art. 25. Wood Piles—For ordinary building work and in situations where they can remain permanently in a wet condition, wooden piles are commonly used to provide



Figs. 26 and 27 Timber pile.

Figs. 28, and 30 R. C. C. pile, square and circular.

Figs. 31 and 32 Cast in situ R. C. C. pile.

cheap foundations. Only suitable timber should be used for the purpose. Wooden piles are either circular 8″ to 18″ diam. or square 6″ x 6″ to 18″ x 18″ in section.

Wooden piles are driven by blows delivered by a drop hammer, as described in the next article. To receive the

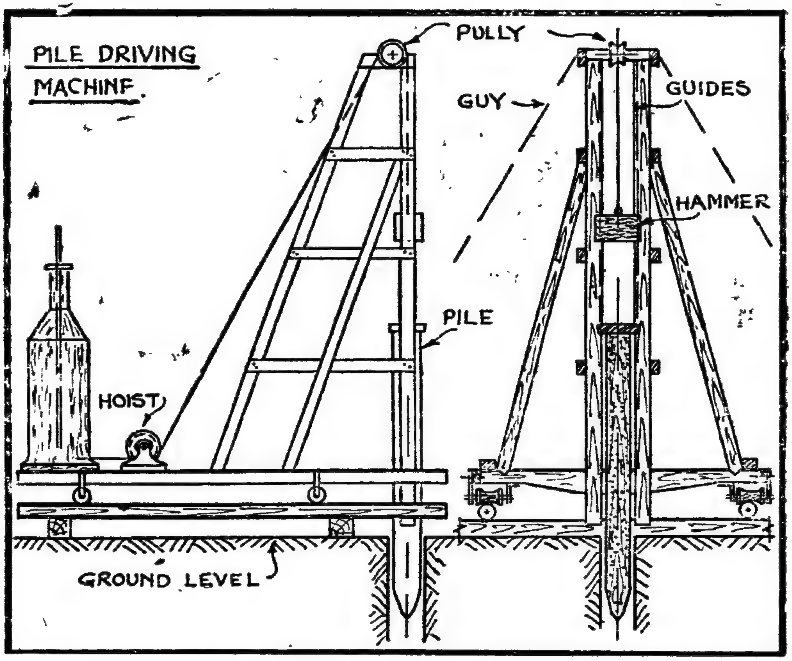
shock of the blows and to prevent the timber from brooming, an iron ring is provided at the top of the pile. See figs. 26 and 27. The lower end of the pile is made pointed and is also protected by a conical iron shoe to facilitate driving. The tops of the piles are cut off below permanent low-water mark and a frame work is provided to lay concrete and footings of walls and columns. This often needs deep excavation, sheet piling and pumping.

Art. 26 Concrete and Reinforced Concrete Piles —*Precast Piles*—For all permanent work where heavy loads have to be sustained reinforced concrete piles are used. They are either pre-cast or cast in-situ, and are suitable in almost any situation. Plain concrete piles are also used for short lengths, and are cast first by driving a steel tube to form a vertical hollow portion where concrete is subsequently filled in.

Pre-cast Concrete Piles can be manufactured coveniently at a place away form the site of works and coveyed to the place where they are to be driven. They are always reinforced to withstand the handling and driving stresses. The main reinforcement which is longitudinal, should be placed symmetrical in the cross section of the pile. See Figs. 28, 29 and 30 for typical sections of square and circular R. C. C. pre-cast piles. Proper devices should be provided for lifting and slinging the pile, which is sufficiently strong to withstand the stresses while being conveyed and driven. Pre-cast piles are given sufficient time for curing and gaining strength in the manufacture's yard. But they are subjected to heavy shocks and vibrations while driving, particularly when the pile is slender and longer than 60 to 75 feet. Thus in some cases it is uncertain to say in what state of strength the pile remains when finally driven in position.

The length of the piles to be cast for each group of piles is pre-determined by a test pile. But in some cases piles have to be lengthened after being driven, and joints have to be made for extra lengths, either on account of the hardpan being at a depth greater than that previously

estimated, or due to the shattering of the head while driving. This is not only expensive and leaves a weak point in the pile, but involves loss of time in making a joint and allowing it to set and harden. The size and the length of a pre-cast pile is also determined by the facility of transporting them. Often a large number of slender piles is preferred to a smaller number of thick and heavy piles.



Figs. 33 and 34. Pile driving machine Drop hammer type.

When it is difficult to ascertain the exact length of a pre-cast pile required for any work due to the varying depth at which the supporting hardpan occurs, certain standard minimum lengths are cast and small pieces of pre-cast lengths are added as required, tongue and grooved or spigot and socket joints being used to connect each other. Sometimes standard lengths of pre-cast R. C. C. units are cast, which are assembled and driven.

Art. 27. Pile Driving—*Pre-cast and Cast-in-situ.* (i) *The Drop Hammer Type*—In its simplest form, the device for driving a pile consists of a drop hammer of about 2 to 4 tons weight. A rope is attached to the hammer, and is used for raising it with the aid of a winch. The force required for driving a pile is derived by raising the hammer to the required height and then allowing it to drop down through the guides, on the hood of the pile or pile cap. A typical pile driving machine is shown in front and side elevations in Figs. 33 and 34 respectively. The top of the pile is protected by a pile hood containing a cushion of hard-wood blocks and the lower pointed edge is reinforced by an iron shoe for effective driving. For a drop hammer type, the frame is of timber and rests on rollers for lateral movement from place to place for driving. For driving batter piles i, e. piles at an angle or inclined piles, the guides are capable of occupying a slanting position at a desired angle.

(ii) *The Steam Hammer Type*—The driving force in this type is derived from steam hammers for quick work, and a larger number of blows could be delivered at the head of the pile in a short period for driving. Both single acting and double acting steam hammers are employed. Steam hammers are specially used for driving sheet piles, steel tube casings of cast in-situ piles, and where small vibrations are required to be set up in the casing tube. They are mounted on specially designed steel frames which could be conveniently used for driving piles under different conditions. Mobile type of pile drivers are also designed and are mounted on caterpillars. They have guides suspended from the edge of a crane, which replaces the frame of a normal pile driver. For pile driving work, in water, pile drivers are also mounted on boats.

(iii) *Use of Water Jets*—For soft driving, the effect of damaging the piles by a hammer could be minimised by the use of water jets. Nozzles are provided in front of the pile shoe and by the sides as well, and water of the required

pressure, upto even 100 lbs. per sq. in. is jetted through them. The front nozzle is intended to soften the loose material and the side ones to lubricate for easy driving. Driving of piles by water jets is often accompanied by difficulties in maintaining the piles in plumb. An internal pipe placed longitudinally in the body of the pile is more advantageous to supply water for the jets and gives a better balanced drive, than external side pipes.

(iv) With the aid of a *Driving Drum and Winch Crab*- The driving drum is fixed at the head of the pile and the pile is rotated gradually by applying a torque from winch crabs through ropes. This method is used for driving the screw piles and disc piles of iron and steel in clayey soils and silt of a homogeneous nature and when it is free from burried boulders and trunks of trees, etc.

Art. 28. Bearing Power of Piles:—In the case of bearing piles their bearing power depends on their safe resistance to crushing. The pile is considered as a column and its bearing power is caculated on the sectional area and the safe permissible stress in concrete of the pile. Bearing piles are " driven to refusal" i. e., until no penetration takes place under the last few blows. This results when a pile reaches a bed of hard rock or hardpan on which it rests and to which the load is transferred.

But the bearing power of friction piles is determined by a study of their behaviour under the effect of last few blows. As they are not driven to rock level, under each blow a proportional penetration always takes place. On this basis several imperical formulae are framed

Load Tests on Piles—Piles are also tested for their bearing power by applying static load tests. A loading platform is built up on the head of the pile to be tested and is loaded by sand bags or heap of iron and rails, as in the case of soils. Settlements are observed and the magnitude of the failure load is determined. A graphical study is generally resorted to. A suitable factor of safety is applied

for obtaining safe load on the pile. Jacks are also used to deliver the test load to a pile.

Art. 29. Iron Piles—*Disk Piles and Screw Piles.* Iron is also used as a material for piles. A disk pile consists of a hollow shaft of upto 12 ins. diam. and a disk of upto 6 feet diam. These piles are quite suitable for homogeneous types of sandy and clayey soils with silt. For greater depths screw piles are used. Usually a pilot screw of a much smaller diameter is provided at the lower end. Disk and screw piles are driven by a capstan wheel or drum of about 15 ft. to 20 ft. diam. fixed rigidly at the head of the pile. This drum is rotated by means of ropes worked by winches. Water Jets are also used to facilitate the driving process.

Art. 30. Pile Driving Formulae—(*i*) *When a Drop Hammer is used,* neglecting the effects of elasticity. According to one formula, considering the effect of impact on in-elastic bodies, we have, safe load on pile, given by:—

$$P = \frac{WH}{CD} \text{ tons (This is known as Brix formula.).}$$

Where, W = weight of drop hammer in tons.
H = fall of drop hammer in ins.,
D = distance in ins. that the pile is driven by the corresponding blow.
C = constant, usually taken as 6 to 8 as factor of safety.

If the weight of the pile w in tons is taken into account then, we have,—

$$\text{Safe load on pile, } P = \frac{W^2H}{C\,(W + w)\,D} \text{ tons.}$$

This is also known as Dutch formula with C as the factor of safety.

(ii) *When a Drop Hammer is used,* considering the effect of elasticity. If elasticity of the pile and the drop hammer is taken into account then, safe load on pile,

$$P = \frac{4\,W^2\,wH}{C\,(W + w)^2\,D}$$

For the value of D in the above formula, an average of last five to ten blows is taken. It should not be less than 1″.

(iii) *When a Steam Hammer is used,* Engineering News formula :—

Safe load on pile, $P = \dfrac{2\,WH}{C+D}$ tons.

Where H is in feet and D is in inches. The value of D is an average of last 20 blows.

$C = 1$ when a drop hammer is used and 0.1 when a single acting steam hammer is used.

For a double acting steam hammer, we have

$P = \dfrac{2\,(W + ap.H)}{D + 0.1}$ tons a = area of piston, sq. ins.
p = steam pressure, lbs./sq. in.

This is also called 'Wellington' formula.

(iv) *Hiley's Formula*—For steam driving—Recently attempts are made to classify the type of driving needed for different types of soils, such as, easy, medium, hard and very hard driving and assign different values for the respective contrants appearing in the piling formulae. The length of the pile also has an effect on these constants. Hiley's formula is stated as the total resistance of the ground:—

R = Ultimate resistance of the ground to penetration, plus wt. of hammer W, plus wt. of pile w.

$= \dfrac{xW.\,yH}{D + 0.5C} + W + w$

For obtaining the safe or permissible load on a pile 50 percent of R is only taken.

x = efficiency of hammer blow, which depends upon the ratio of weight of pile to that of hammer. See table VI.

y = conversion factor for actual fall to obtain effective fall. 0.8 for drop hammer; and 0.9 for steam hammer and 1.0 for a freely falling weight. H in inches.

C = temporary elastic compression in inches. See table VII.

Art. 31. Reinforced Concrete Piles. *Cast in-situ Piles*—These piles are cast on site, in the position which they are intended to cccupy finally. Principally the casting of such piles involves the operation of first boring a hole in the ground and subsequently filling up with concrete after the necessary steel reinforcement is introduced.

Table No. VI. Values of x for R. C. C. piles.

W/w	½	1	1½	2	3	4	5	7
R. C. C. Piles	0.75	0.63	0.55	0.50	0.42	0.36	0.31	0.27

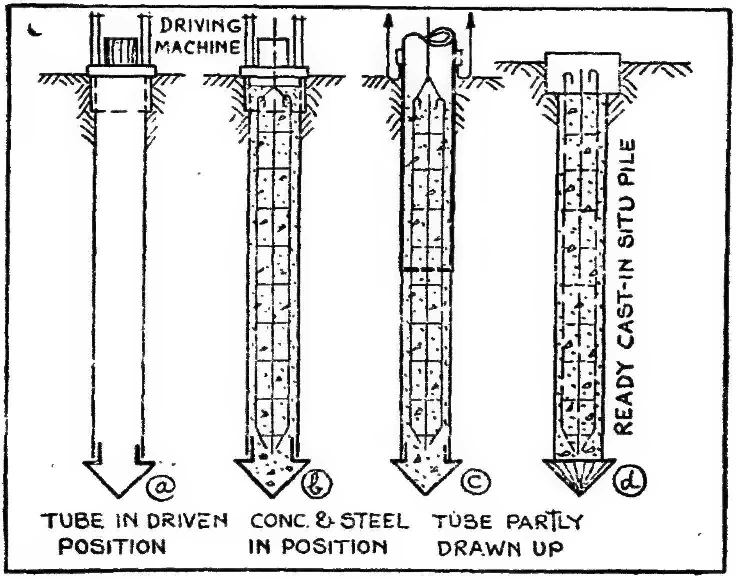
Table No. VII. Temporary elastic compression C Inches.

Length of Pile ft. R.C.C.	Type of driving and stress intensity in pile lbs/sq.in. Easy driving — 500, Medium driving - 1000; Hard driving — 1500; Very hard driving - 2000			
20	0.28	0.47	0.65	0.79
40	0.34	0.59	0.83	1.03
60	0.40	0.71	1.01	1.27

This class of piles has some advantages over pre-cast piles. There is no wastage due to cutting off the top, or delay in lengthening, curing and transpoting as in the case of pre-cast piles. If the cast in-situ piles are sunk by boring. instead of by driving, disturbances in the soil and the probable dangers to the existing heavy structures could be avoided

The cast in-situ piles fall into the following principle catagories,—

(i) *Piles which are protected by a steel tube or shell*—An outer steel shell or tube is driven into the ground with the aid of an inner steel core. The inner steel core is collapsible and removable after the required depth is reached. Reinforcement is then introduced in the steel tube, which is then filled with concrete. The outer steel tube is usually corrogated and reinforced laterally with $\frac{1}{4}''$ diam. bars. In Fig. 31 is illustrated such a concrete cast in-situ pile with the outer corrogated steel shell left in position as a permanant



Figs 35. 36. 37 and 38. Showing the different stages of cast-in-situ pile driving-Simplex type.

casing and the inner collapsible core partly drawn out. A view of the completed pile is shown in Fig. 32.

(ii) *Piles in which concrete is not protected at the sides*, and is allowed to come in contact with the soil in which it is driven. This is the second catagory of cast in-situ piles. The hollow steal tube which is used while driving, acts like a form work for concrete. In hard ground and in made up soils a cast iron shoe of the inverted conical type is used to

facilitate driving. Otherwise in soft and homogeneous soils, a quality of dry concrete of about 3 cu. ft. is put at the foot of the tube instead of the cast iron shoe, and is driven by a rod hammer from inside.

Art. 32. Cast in-situ Pile Driving-(a) *With C. I. shoe*—The section of the pile is the same as the driving tube. The following is the sequence of operations generally adopted in the type of concrete pile known as Simplex concrete pile, where C. I. shoe is used.

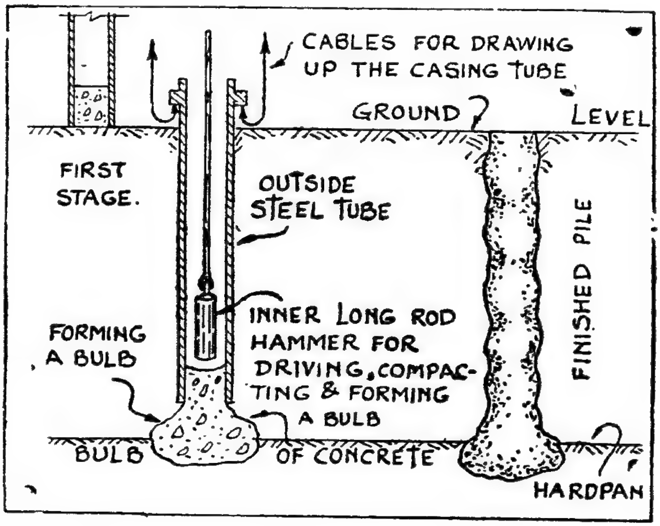


Fig. 39. 40 and 41. Driving of Bulb Piles.

(i) Cast iron shoe is placed is position on the ground where the pile is to be driven.

(ii) A hollow steel tube is placed on this C. I. shoe and the two are driven into the ground to the required depth. See Fig. 35. The driving force is applied to the steel tube.

(iii) Steel reinforcement is then lowered centrally into the tube.

(iv) Concrete is poured into the tube about 3.0 ft, each time and under its own weight gets consolidated.

A long steel rod hammer induces the downward decent and cosolidation of concrete. See Fig. 36.

(v) The steel tube is then drawn out as shown in Fig. 37, each time a 3 ft. length is filled up.

(vi) The final pile after completion with pile cap on it, is shown in Fig. 38.

Art. 33. The Bulb Pile or Pedestal Pile—The lower cast iron shoe as mentioned in the previous article is omitted and in its place a small quantity of dry concrete is placed at the foot of the hollow steel tube before driving and the driving is effected by ramming this concrete from within and with the aid of a long rod hammer. See Fig. 39.

After the final depth is reached, a fresh quantity of about 3. ft. concrete is poured in and the steel casing tube is partly drawn up. On ramming, this concrete bulges out aud forms a bulb which increases the bearing capacity of the pile at the foot. See Fig. 40. The reinforcement is lowered after the foot bulb is formed. Similar Concrete bulbs would also be formed at intermediate points in the whole length of the pile, which improves the side grip of the pile in the ground. See fig. 41. In another system, the foot bulb is formed by a small explosion.

Art. 34. Tamped piles or Expansion Piles—The section of pile is more than that of driving tube. These are cast in a similar manner to the Simplex Concrete Pile, except that at the lower end of the tube a sleeve is fitted as shown in Fig. 42. For every 2 or 3 ft. of withdrawal of the tube, it is again forced down slightly to drive the concrete out of the lower end of the sleeve and to ram it as well. The piles thus formed are slightly thinner in section. See Fig. 43. The piles thus formed are also dense and homogeneous.

Sometimes the *cast iron shoe is omitted* and at the lower end of the hollow driving tube, the sleeve of the tamped pile is replaced by an alligator point. The alligator serves the

purpose of a driving edge and its jaws are closed when the tube is being driven. See Fig. 44. When the tube is being withdrawn, the jaws open and the concrete is forced out, as shown in Fig. 45.

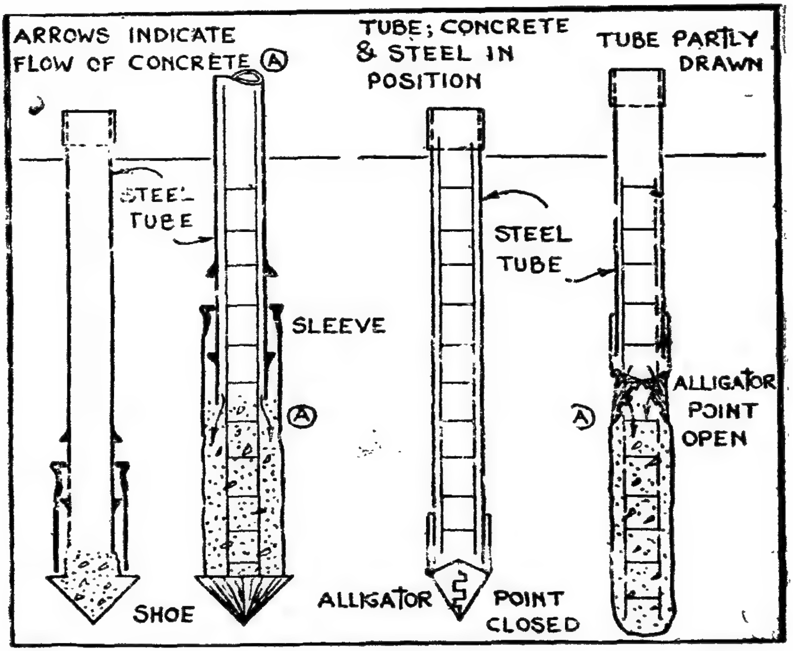


Fig. 42 & 43. Cast in-situ piles. Tamped type with C. I. shoe.

Fig. 44 & 45. Cast in-situ piles. Tamped type with alligator point.

Vibro Piles—In this process, the consolidation of concrete in the hollow steel casing tube is effected by vibrating the entire bulb. By this it is claimed that more dense concrete is formed and the work would be done rapidly and that the piles are stronger.

Art. 35. Sand Piles—These are formed by first driving holes in the soil for the required depth and then filling them by sand. After the sand is consolidated a concrete cap is placed on these piles to take up the load. Usually these piles are not more than 10 to 12 feet long and 10 to 12 inch. diameter.

Art. 36. Grouping of Piles and Pile Caps—While driving friction piles in groups, it should be remembered:—

(i) That the intensity of loading on the soil due to a group of piles does not exceed the bearing power of the soil. Otherwise the whole group of piles will sink bodily.

(ii) That if the piles are driven too close to each

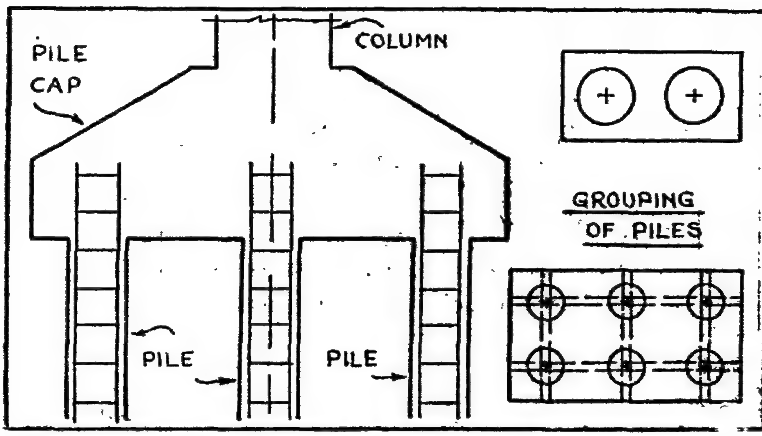


Fig. 46, 47 and 48. Details of grouping of Piles and pile caps

other the compressed soil confined between them is likely to be squeezed out in the course of time, and thereby the piles may loose their bearing power.

On account of this, the spacing is kept usually not less than 30" so 36" from centre to centre between two piles. See Figs. 46 and 47.

After the piles are driven into the ground, their tops are cut to a uniform level and a frame work of beams and a platform of slab is provided for the structure to rest upon. It is necessary that the loads over the group of piles is distributed uniformly as far as possible. But in the case of tall towers and chimneys, due to lateral forces of wind acting on them, the supporting piles are not uniformly loaded. On the windward side the load on piles becomes considerably less than that on the lee-ward side. In such cases, the number of piles required is calculated by taking

half the load on piles without wind pressure. The concrete footings of R. C. C. columns are supported directly over the piles. See Fig. 48. Note the reinforcement of the R. C. C. piles extending into the pile cap.

Batter Piles—In the case of foundation for retaining walls, quay walls, jetteys, piers, abutments, and chimnyes, etc., where there are horizontal forces acting on foundations.

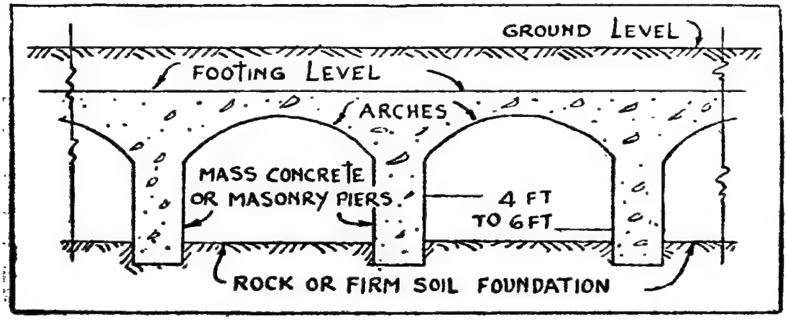


Fig. 49, Pier foundations.

inclined piles called '*Batter Piles*' are provided. These piles are driven by giving an inclination to the guides of the pile driver, as required.

Art. 37. Pier Foundations—This is another form of pile foundation. The piles are replaced by mass concrete or masonry piers of 4 to 6 feet thick and tops of these piers are connected by mass concrete arches or arches of brick or stone masonry, below the footing level. This type of foundation is more suitable for very heavy loads of framed structures on shallow types of soft ground, and marshy or wet places, overlying a rock or firm strata. The piers are founded on the firm strata and thus transmit the load safely. See Fig. 49.

Art. 38. Steel Cylinder Foundations—In the case of very heavy structures, it is advisible to take the foundation upto solid rock below. If this rock strata is deeper than about 15 to 20 feet from the ground level and particularly when clayey soil is lying over it, piles become very slender

and greater in number. To overcome this hollow steel cylinder 3/8" to 3/4" thick and about 4 feet in diam are used to provide the foundation. They are sunk in lengths of 6 to 10 feet by any one of the following methods :—

(i) By blows delivered from a steam hammer.

(ii) By pressure from the hydraulic jacks.

(iii) by excavation with aid of compressed air or buckets or dredgers.

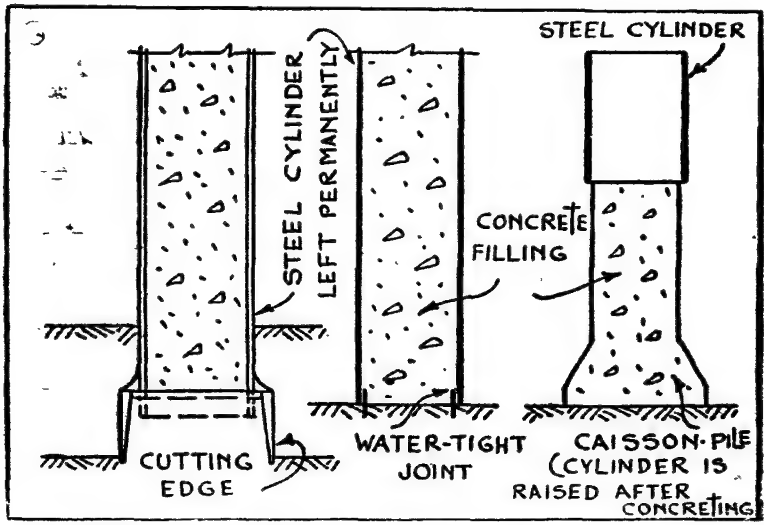


Fig. 50, 51, and 52, Steel cylinders and caisson piers.

(iv) by their own weight or by extra weight added on top, with the aid of a loading platform.

After reaching a firm foundation bed, the cylinders are filled with concrete. One or more cylinders may be sunk, for each column. See Figs. 50, 51 and 52. The first two are suited for rock beds while the last one with a widened base, is designed for resting on a hardpan or hard compact soil. The steel cylinders used for casing, are sometimes left permanently to protect the concrete.

Art 39. Caisson Foundations—These are very similar to cylinders. Sometimes only one large pile is used under

each column. At the lower end there is a strong box called working chamber, in which is carried out the excavation work for sinking the caisson pile. Usually it is heavy enough to sink under its own weight. If there is under ground water, it is prevented from entering inside the caisson by maintaining the necessary air pressure in the working chamber, supplied by means of suitable compressed air pipes from the top. In this ease the top is closed. Air locks are provided for the passage of men and material between the working chamber and the ground level. The

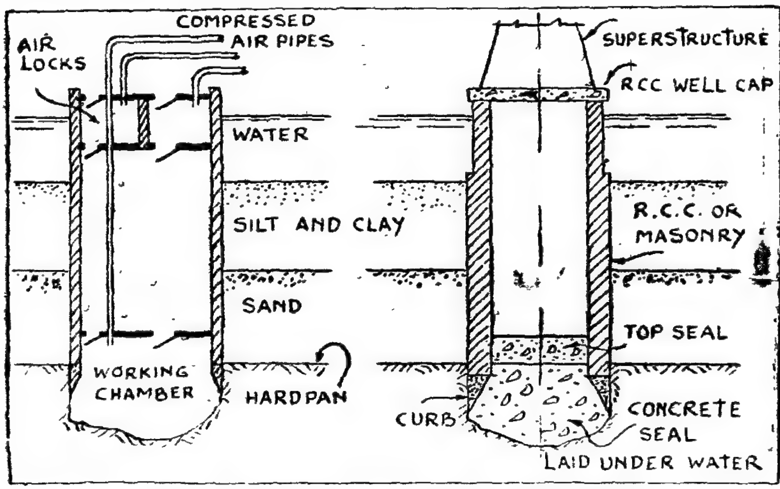


Fig. 53. Caisson! Fig. 54. Well-sinking.

caisson is then said to be sunk by pneumatic process. See Fig. 53. The main body of the caisson foundation can be of either R. C. C. or steel plates.

Art. 40. Well Foundation—Wells of masonry or concrete are also used to provide foundations for columns and piers carrying very heavy loads. They are built on a curb with a cutting edge of the required thickness for the wall, and are sunk by dredging under this cutting edge. Single wells are circular and their diameter varies from 8 to 15 ft. inside. The well gradually sinks under its own weight or by added weight on top, until it finally rests on hard ockr

The well is then filled with concrete. The space inside the well between the bottom concrete seal and the R. C. C. cap on the top, is filled with either concrete of low strength, sand or water. It should be noted that cylinders, caissons and wells have to be maintained in a vertical position while sinking and when left in their final position as well. They should be perfectly plumb. A typical well foundation for a bridge pier is shown in Fig. 54.

Well-Sinking—The normal procedure for well-sinking is as follows:—To excavate on the surface of ground to a small depth. To place the well curb or steining with cutting edge on the bed of above excavation in the required position. To build masonry or cast the concrete wall to a height of about 6 to 8 feet. To dredge from inside, sufficiently lower then the cutting edge to a depth of about 2 to 4 feet. To load the well on top by preparing a loading platform to effect the sinking of the well. To dredge again until 6 to 8 ft. of sinking is obtained. To remove the load and the loading platform. To build the next height of 6 to 8 ft. of masonry or concrete. To repeat the above process in the same order as above. If the water pressure is great and there is heavy inrush of water which could not be coped up with pumps to expose the bed for excavation under dry conditions, dredging under water has to be resorted to and controlled from the top of well. The dredgers commonly used are grab dredgers, orange peal dredgers, and bucket dredgers. Suction dregers are very seldom used in well sinking.

Art. 41. Compartmeat wells and Caissons. Very often, while sinking, wells and caissons go out of plumb due to various reasons such as : uneven dredging and jetting soft pockets of clay met with by a part of their base; boulders touching a part of their base; the base rock surface on which they are to rest being not horizonal; unequal and careless loading on them while sinking; etc. In the case of small wells this is set right by careful dredging, excavating and loading

on their side opposite to that towards which it is inclined, or by operating hydraulic jets, if they are used, or by pulling them against an anchor weight.

But in the case of large size wells and caissons, their total cross sectional area is divided into regular compatments of about 10 ft. by 10 ft. size, arranged symmetrically with respect to their two axes, and the entire process of sinking is controlled by symmetrical dredging and loading of these compartments. If the base has to rest on an inclined rock surface, extra lengths of R. C. C. are built up below that part of the base which overhangs and does not touch the rock surface. Alternately the hump of the rock surface which touches the base of the caisson or well is excavated and removed so as to give a horizontal foundaion bed for it to rest upon.

Art. 42. Resistance of Piles, Caissons and Wells— When piles, caissons and wells are driven in soils, they have to overcome three types of forces :—

(a) The resistance of the soil at the toe or the base for direct bearing.

(b) The friction along their sides and the soil.

(c) In the case of tapered sides ths vertical component of the normal pressure acting on the sides.

Thus the equilibrium equation for the stability of the above could be written as :—The ultimate load,

$$L = pA + fS + N \sin v. S$$

$p =$ the unit bearing pressure of the soil acting on a base area of A.

$f =$ the unit side friction acting on the total side contact area S of the pile, caisson, or well.

$N =$ the unit normal pressure on the sides and v is the angle of the tapered side (if a taper is provided) with the vertical.

The approximate value of f for different soils are given below in pounds per sq. ft. :—

(i)	Soft clay and alluvial deposits	75 to 150
(ii)	Compact clay and silt	200 to 400
(iii)	Compact sand and silt	500 to 1000
(iv)	Compact coarse sand and gravel	1200 to 1600
(v)	Unexposed firm shale and compact gravel.	1600 to 2200

It is very seldom that througout its depth, a pile will pass through only one type of soil. If trial borings at the site indicate different type of materials, say for example, soft sand and clay, silt, coarse sand, coarse sand and gravel, etc, the thickness of the layers of these various materials as certained from the logs of borings, and the corresponding frictional resistances are worked out and added to obtain the total frictional resistance of the pile.

Prestresed Concrete Piles—It may be noted that with the advent of prestressed concrete, piles of the precast catagory are also made of that material. The prestressing cables are passed through ducts in the corners of the piles.

CHAPTER IV

Excavation and **Foundation Concrete**

Foundation plans and setting out. Dry excavation, Loose soils and dry evcavation. Sheet piling, Excavation in rock, Water in excavation Concrete and its uses in foundation. Aspects of concrete making.

Excavation

Art. 43. General–Foundation Plans and Setting out—The methods of providing a suitable foundation to a structure at its base, for transferring its load to the soil below, have been hitherto explained. The next step is to excavate, into the ground to reach this soil of the required type and bearing power and to prepare a bed of foundation on which is laid the foundation of a structure.

After the foundation designs are ready for any structure, foundation plans are prepared for the guidance of the construction engineer showing the widths and depths of excavation. The widths shown in the plan are those at the bottom and the depths indicate how deep the excavation should be taken to reach the desired soil. It may be noted here that though the excavation depths are marked on the plan, they are merely a guide, and it is the responsibility of the construction engineer to see that such a soil of the estimated bearing power is actually met with. For this purpose, the excavation depth may be changed as required.

The next step is to set out the centre lines of the respective walls and columns on the ground together with the corresponding foundation widths to facilitate excavation.

Ordinarily the common implements used for excavation are pick axes, showels and spades. But for removing boulders crow-bars and chisels with heavy hammers are best suited. In hard rocks the operaiion of blasting is quite essential to proceed with excavation.

Art. 44. Dry Excavation—The excavation of foundation pits is very simple, if the soil is firm, the depths are moderate and no underground water is met with. But in the case of soft soils, such as loose earth, clay and sand, the sides of excavation require supports to prevent them from falling in. The supports essentially consist of boarding planks or poling

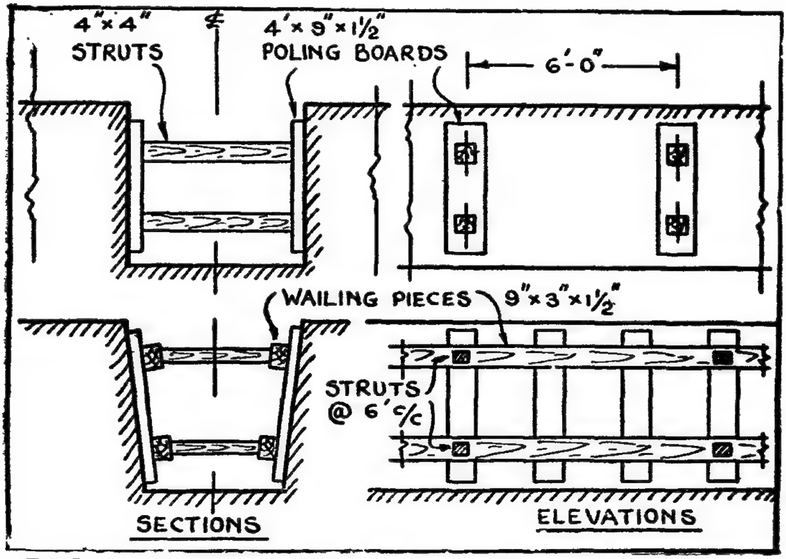


Fig. 55, 56. Supporting the sides and edges of excavation at intervals.
Figs. 57, 58. Supporting the sides and edges with continuous wailing board.

boards, wailing pieces and struts. The various ways in which the above members are arranged, depend upon the strength and the type of the support required. The arrangement is known as Timbering or Shoring.

In Figs. 56 and 57 are shown the methods of supporting the sides of excavation where the ground can stand a vertical cutting during excavation but afterwards may yield and the edges may crumble down. The vertical boarding planks are kept at a suitable interval and are supported by struts, the wailing boards being omitted in this case. If the earth is slightly softer, continuous wailing boards at top and bottom of boarding planks are used as shown in Figs. 57 and 58. The boarding planks are also used at a shorter spacing.

Art. 45. Loose Soils and Deep Excavation — In the case of clayey and sandy soils, the poling boards have to be arranged in a close manner. The usual practice is to arrange these planks vertically as shown in Fig. 60 and 61 but sometimes it is also found convenient to place them horizontally as shown is Fig. 59. In the latter case, vertical poling boards

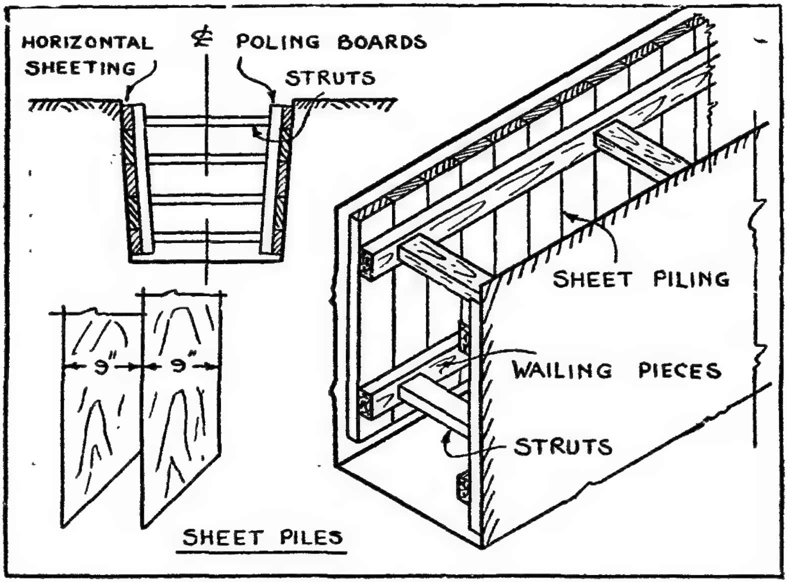


Fig. 59, 60. Showing and strutting of loose soils
Fig. 61 Showing the lower ends of sheet piles

have to be used at regular spacings. Horizontal boarding is used specially when the soil can stand cutting for some time. They can then be spaced at some distances instead of touching each other. The vertical arrangements of the poling boards as mentioned in the former case is commonly known as sheet piling. To facilitate driving, the planks used for sheet piling are pointed at their lower end as shown in Fig. 61, and in hard ground they are provided with iron shoe and iron cap. They are ordinarily driven by a falling weight, but for speedy work steam hammers are used. Sheet planks should be tongued and grooved where water and running sand have to be retained.

Steel sheet piles are also used instead of wooden ones, and have the following advantages:—(i) They can sustain greater pressure; (ii) They can be driven in advance of excavation; (iii) They can be driven to a greater depth; (iv) They could be reused for a greater number of times. (v) The interlocking between the piles can be secured more effectively. However, steel sheet piles are more costly than the wooden ones.

Deep Excavations—With one length sheet piling, a depth of about 8 to 10 feet can be reached. But for deep excavations the timbering is carried out in different sections. For each section the width is increased at the top by about 1′-6″ to 2′-0′ on either side. In Fig. 62 is illustrated a method of timbering in two storries, in the case of a strench for deep excavation for a wall.

For 'Basements and cellers of buildings excavation has to be carried out for the entire area and it is often not possible to arrange the struts horizontally against the two sides of excavation. This difficulty is overcome by placing the struts in an inclined fashion. Note the use of bearing plates and pairs of wedges in Fig. 63 at the lower ends of inclined struts for transferring the earth pressure to the ground below. The wedges facilate the removal of struts quickly and easily. For basement and cellar excavation nearby a road or an adjoining buildig, steel sheet piling is used, as the banks of excavation have to be held with rigidity and strength.

Art. 46. Excavation in rocks—This is carried out with the aid of blasting. The various operations in blasting are:—(i) Drilling a hole of about $1\frac{1}{2}''$ diam. either with a jumper or a rock-drill; (ii) Filling the hole with the required quantity of blasting powder and closing the remaining portion of the hole with a selected tamping clayey material; and finally (iii) Blasting the rock. A fuse of a sufficient length is used to ignite the blasting powder and to allow the person to run to a safe place after lighting.

Art. 47. Water in Excavation — As the excavation depth increases, it is generally expected that under ground water will be met with. The presence of water makes it difficult to proceed with excavation. The following are the various methods used to deal with water in excavation.

(i) *Simple Drains and Sumps*—Moderate amounts of water are disposed of by means of drains excavated by the side of the trench, all draining into common sumps provided at the lowest point, and from which the water is bailed out by means of buckets or hand pumps.

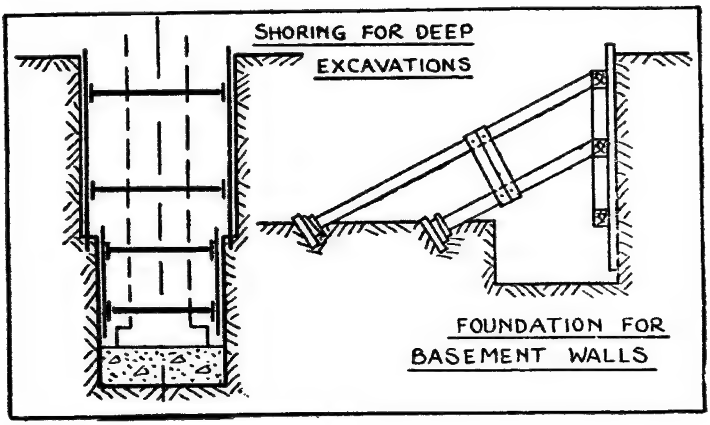


Fig. 62. Shorting for deep excavation.

Fig. 63 Shoring for basement excavation in locse soil.

(ii) *Cofferdam and Pumping*—But large quantities of water require special methods to be used to control and remove them. The common method of keeping away the water from the site of excavation is by putting up a cofferdam of earth, sand bags, puddle clay, sheet pile or crib cofferdam. They enclose the area whithin which the foundations are to be laid. A typical puddle clay sheet pile cofferdam and crib–sheet pile cofferdam are shown in Figs. 64 and 65.

Cribs are used where there is rock at the bottom of water and sheet piles could not be driven. They are stabi-

lised by rock spoils filled inside them and seet piles are fixed on the water side.

Leakage and Boiling—After the site for excavation is enclosed and when the inside excavation is in progress, if there is a strong underground water current or water pressure, particles of small size gravel and sand are forced up from the bed of excavation and thereby give an appearance of *boiling*. Such boils cause serious disturbances of soil in the foundation material and should not be allowed to form. It should be remembered that the purpose of a cofferdam is not to completely exclude the water, but to minimise it within the limits of practical pumping. The cofferdam is constructed

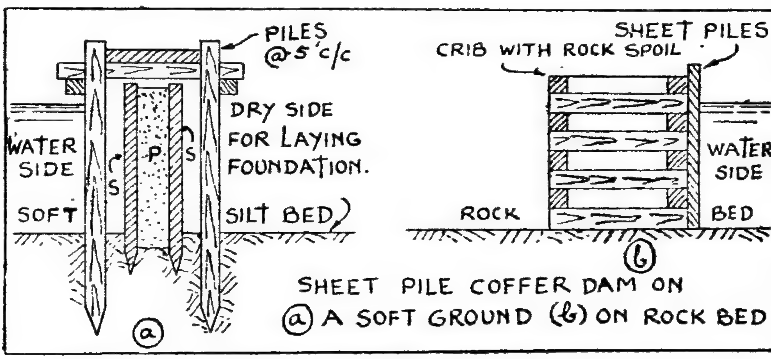


Fig. 64. Puddle cofferdam. Fig. 65. Crib cofferdam.

in advance and the water is pumped out to expose the bed of soil and to create dry conditions for laying foundation.

(iii) *The well-point Method*—In this method, the area to be excavated is surrounded by a row of pipes sunk vertically to a depth deeper than that to be reached by excavation. At the bottom of each pipe a perforated metal tube fitting is provided, known as "well-point". The tops of all pipes are connected by a common horizontal suction pipe. The underground water is drawn out through this piping system and the entire area is thus dried out to take up normal excavation by showels and spades. Sometimes, the well-point method is assisted by a barrier of sheet piles.

(iv) *Caisson and Well Excavations*–By dredging and pneumatic process. For deep evcavations as in the case of foundations for bridge piers, caissons are used to keep away the water during excavation of foundation. The required air pressure is maintained in the caisson box or the working chamber, see Art. 39, which is sunk gradually by excavating inside and around the working edges.

(v) *Chemical Process*—Under favourable conditions where soils are of a permeable character, their stabilization can be effected by chemical methods. The soils are impregnated by suitable chemicals which subsequently harden and form one homogeneous mass with increased power of resistance to loads. The pores in the soil are sealed up. By this process an entire area may de hardened or any weak part of a foundation may be treated. The cementation process adopts the impregnation of sandy soils, alternately, with a mixture of silicate acid and water under high pressure, and a salt solution. In some cases, cement grouting through perforated pipes is also employed. The cement used may be also in a dry state.

(vi) *Freezing Method*—If water is present in very fine sand, and clayey soils, excavation for foundation becomes very difficult. To keep out the water from the foundations, freezing of the soil is sometimes resorted to around the site of excavation where the foundations are to be laid. A freezing mixture is circulated through the pipes which are driven into the soil all around the site to be excavated. After a certain period which may extend over several days, the soil round about the tubes gets frozen and forms into a wall of impervious mass. Within this enclosed area, excavation for foundation is carried out easily.

Though the above methods of dealing with water in foundation are described separately, very often, a combination of two or more is required. It should be remembered that while removing the underground water, the stability of the strata should not be disturbed.

Foundation Concrete

Art. 48. Concrete and its use in Foundations—The use of concrete is very common as a material to be laid directly over the foundation bed for transferring the load of structure to the soil below. It possesses both the essential structural properties of strength and durability and is adaptable to almost any condition in foundation. It offers a solid base to walls and columns to rest upon. This is quite essential for supporting structural members which are built up of independent small units such as stones and bricks. It is essential that a foundation engineer must have a fundamental and a thorough knowledge of the technique of making concrete of the desired properties from the available materials.

Concrete is an intimate mixture of cement, water, and aggregate, designed to imitate the structural properties of a good natural stone. Instead of cement, under ordinary conditions, good lime is used as a binding material. But only hydraulic lime or cement should be used in wet foundations. Plain concrete has great compressive strength but has less strength in shear and tension. In fact, it is used in combination with steel to resist great tensile and shear stresses. It is then termed as *Reinforced Cement Concrete* or R. C. C. Both plain and R. C. C. are widely used in foundation work. The following is a note on the respective ingredients of which a concrete is made up.

Aggregate–*Coarse*–Should pass through a sieve of the maximum specified size and be retained on a 3/16 in. mesh sieve. It should consist of equal parts of material between the maximum size and the middle size, the middle size and 3/16 in. For example if 3/4″ is the maximum size, then the middle size is 3/8 in. No oversize materials are normally permitted in the aggregate; but in mass concrete work 12 to 15% of the over size material by weight may be used. Either broken stone or shingle may be used as aggregate. and should be clean. free from loam and vegetable matter. The particles should be angular and approximately cubical

in size. It should vary in size to secure perfect grading and dense, uniform concrete with all the voids filled up.

Aggregate – *Fine* – This is obtained from broken stone or sand from streams, rivers and pits. All grains shall pass through a size of 3/16 in. mesh sieve and shall consist of properly graded and sized particles upto 1/16 in. Sea sand should not be used for making concrete. Sand should not be too fine and the grains should vary uniformly in size.

Cement—The cement used snould be of approved manufacture and should comply with the latest British Standard Specifications for the type of cement to be used on the works.

Water—Only that water which is fit for drinking shall be used for concrete work. The water-cement ratio and the exact quantity of water to be added each time for any type of concrete is specified by the engineer in charge, for mixing concrete.

Art. 19. Aspects of Concrete Making—The following are the salient features in the making of good concrete. It should be remembered that each stage has its own importance in imparting strength and durability to the resulting concrete and also in making the entire operation an economical one.

(i) *Proportioning Concrete*—The strength of concrete is governed by the ratio of its ingredients and size of the aggregate, whereas its durability depends upon its density or the closeness with which its ingredients are packed. It should always be the aim of a concrete designer to produce a dense and homogeneous concrete which will give the desired strength with a minimum paste of cementing material. For the theory of concrete making, the reader is referred to A Text Book of Reinforeed Concrete, by R. S. Deshpande and G. J. Kulkarni and a Text Book of Engineering Materials by G. J. Kulkarni, or any other text book on the subject.

(ii) *Mixing of Concrete*—The aim of mixing is to prepare a homogeneons concrete so that each particle of the aggre-

gate is covered with a film of cementing material and the whole concrete is workable. The materials are measured in each batch mix and are mixed either in machines or by hand. The present practice is to adopt machine mixing in all superior works.

(iii) *Transporting Concrete*—On big works extending over wider areas, the problem of transporting concrete from a central mixing position deserves a careful consideration. During the transport of concrete segregation of the ingredients should not be allowed to take place, and its homogeneous nature developed during mixing should not be lost. It should be deposited in its final position of rest in less time than that specified for the initial set of cement, from the commencement of wet mixing. On large areas, concrete towers are constructed when ready mixed concrete is raised and distributed for depositing with the aid of chutes or inclined troughs or pipes radiating from it. For easy and quick transporting, concrete pumps are also adopted, and the use of pneumatic guns and concrete pumps is also becoming common in large construction works. However the transporting of ready mixed concrete should not be recommended for very great distance as this may affect its homogeneous natnre and set up initial setting.

(iv) *Placing of Concrete*—Concrete should be deposited on a foundation bed with care so that the ingredients are not separated and honeycomb texture is eliminated. It should not be thrown from a height. It should be laid in regular horizontal layers of thickness not exceeding 6″ to 9″. Similary electrical or pneumatic vibrators are used to produce dense concrete. In any case, concrete should on no account be disturbed after the intial set commences. Expansion joints and construction joints should be deligently provided wherever required.

(v) *Curing*—Freshly laid concrete should be kept thoroughly wet for about a fortnight for curing. During this period, certain chemical changes take place in concrete and

the whole mass hardens and gains strength. Wet gunny bags soaked with water are spread on concrete. Earth bunds longitudinal and cross-wise are put on the surface of concrete and kept filled with water during the curing period.

(vi) *Form work*—Wherever required, form work should be provided to support fresh concrete until it hardens sufficiently to support its own weight and the superimposed weight. The essential requirements of a good form work are that it should be rigid and should not be deformed when in use. It should also be capable of being removed easily and quickly after use.

The thikness of foundation concrete below walls and columns is shown in figs. 8 and 11, but its minimum value is taken as 12 ins. to 15 ins. If the structure rests on solid rock, the layer of concrete may be eliminated and the wall or column could be made to sest directly on the prepared and chiselled rock bed.

CHAPTER V

Stone Masonry

General consideration. Classes of masonry---their important features. Walls and their types-load bearing, panel and composite walls. Framed structures. Terms used.

Dressing of stones, quarry dressing and dressing at site. General principles of stone masonry construction. Classification of stone masonry, Ashlar masonry. Rubble masonry--coarsed rubble and random rubble, Methods of securing heavy stones to be lifted. Use of jaggles, dowels and cramps,

Art. 50. General Consideration—*Classes of masonry and their important features*—Masonry is the art of building in stones and bricks. Except in the case of dry masonry some kind of mortar is invariably use as a binding material for these units. Sometimes the term masonry is confined where only stones are used and the term brick laying being used if bicks are employed instead. In some cases stone is used in combination with brick or concrete to form composite masonry.

Following are the salient features of the two principal classes of masonry:–(i) Stone Masonry, (ii) Brick Masonry.

(a) The materials used in stone masonry walls are either natural stones worked to rectangular blocks and roughly dressed, or artificial stones manufactured from concrete to the required size and to resemble a stone. On the other hand bricks are clay products designed to prossess good strength, durability and insulation properties at a moderate cost.

(b) Stone walls built of solid cubical blocks are stronger and more durable than brick walls. In public building and works of monumental nature and of national importance where cost is not a primary consideration, stone masonry is best suited.

(c) When compared with rubble masonry, brick masonry affords proper bonding, rapid construction and requires

proportionately a smaller quantity of mortar. The work of constructing a brick masonry wall is more mechanical in nature, whereas for stone masonry some extra time is spent in dressing a stone and setting it into the wall.

(d) Brick walls can be smaller in thickness up to 3″ to $4\frac{1}{2}$″ whereas a stone wall is not ordinarily buit of a thickness less than 15 ins. Unless the bricks are of a first class quality, the exposed faces require protection by plastering to prevent the absorption of moisture. This increase the cost of thin walls. But thin wall have a distinct advantage of giving a greater available floor area in the interior of a building for occupation.

(e) When heavy architectural mouldings with greater projections are required, stone is better suited. But for light ornamentl work bricks can be conveniently shaped and subsequently covered by plaster.

(f) Stones are quite unsuited to certain atmoshperic conditions and consequently distingrate badly. Hence great care should be taken in the selection of a building stone to suit the local atmospheric conditions.

(g) For external wall faces, stones do not require rendering while bricks have to be protected in many cases with a plaster coat.

Art. 51. Walls and Their Types—Structurally walls are classified into—(i) Load bearing walls; (ii) Panel or Screen Walls; and (iii) Composite walls. A brief discription of these types of walls will now be given.

(i) *Load Bearing Walls*—Due to the introduction of new materials such as concrete, simple and reinforced, precast block both solid and hollow, light weight partion panels, etc., the traditional method of constructing a wall as load bearing member, modified in many ways. But load bearing walls serve both the purposes of supporting the floors and roofs and that of screening and partitioning to enclose

a space in a building. They should therefore be designed to withstand the loads to be carried by them and should be built on a continuous foundation to rest on a firm soil.

(ii) *Panel or screen walls* are primarily intended for secrening and partitioning with a view to enclosing space. They are very commonly used in framed structures and are built between columns and beams as filler walls. They are non-load-bearing members and are only strong enough to stand their own weight. The main load of the structure is borne by the columns, beams and floors. Bricks, hollow or solid pre-cast blocks, and such other light weight materials and propritory products are used for their construction.

(iii) *Composite walls* are those in which the facing and the backing cosist of diffierent materials. The common variety of a composite wall consists of blocks of stones as facing materials bonded to bricks or concrete as backing. Other materials like stone slabs, facing bricks, glass, tiles, etc. are also used. The facing blocks are sometimes secured to the backing by means of metal ties and cramps. Detailed method of constructing composite and other varities of walls are given later. In this chapter the construction of stone masonry walls is dealt with. They are essentially load bearing walls.

Art. 52. Framed Structures—In a framed structure, the floors and walls transfer their loads to the supporting beams, which in their turn, by virtue, of their resting on columns, transfer their loads to them. The columns then finally transfer the load to the soil below by any of the method given in the early chapter. Framed structures have some advantages over walled structures. They are given below.

(i) Possibility of keeping in progress the work of several building trades at a time. The frame work of the building can be kept in progress on the upper floor and the walling and the other finishing work can be carried out on the lower floors. This results in a greater speed of erection.

(ii) Costly materials of greater strength can be used and the sections of the members can be smaller. Consequently an increased floor space may be claimed.

(ii) In made-up soils and for pile foundations, framed structures are the best suited.

(iv) The classification of load bearing and non-load-bearing members enables cheaper materials to be used for the latter where strength is not the criterion.

(v) Buildings in earthquake areas are better desined as framed structures.

(vi) In the case of multi-storied buildings, stereo-typed construction work from floor to floor is always economical. Framed structure admits of such a design, and if it is of reinforced concrete, the form work for slabs, beams and columns can be used several times.

However proper care should be taken to secure bondage between the members of the frame and the panel fillings. It is generally observed that small buildings are quickly and very conveniently disigned and constructed as walled structures.

Three materials are commonly used for the construction of the frame work of a building:—(a) wood, (b) steel, and (b) reinforced concrete. Each has its own advantages. The first one is used for cheap and temporary work whereas the lost two are the best suited for a permanent work. Steel has a disadvantage of recurring cost of maintenance and also cannot be used alone when fire proof qualities are needed. These disadvantages are ovecome by the use of reinforced concrete, and in addition the sections can be economically designed due to the continuity of beams and columns and to the monolithic nature of the structure as a whole.

Art. 53. Terms Used—The following are terms used in the construction of masonry walls:—

(1) *Stretcher* is a stone or brick which is laid lengthwise with its face parallel to the face of the work. It may be

noted that all khandkies in stone masonry are stretchers. Strechers add to the longitudinal strength of a wall.

(2) *Header* is a stone or brick which is laid with its length perpendicular to the face of the wall. In thicker walls, instead of a single header a row of headers is used. If the wall is of stone masonry these headers overlap a distance of not less than 6 ins. and the joint thus formed between the headers is known as "*stone joint.*" Headers are also termed as "*through stones*" and they extend from one face of the wall to the other. "*Bond stone*" is also another name which is applied to header in stone masonry. Headers add to the transverse strength of a wall and secure bonding between the facing and the hearting.

(3) *Bond* is the method of arranging stones or bricks in masonry work so that they are tied together to form a solid mass with proper cohesion. The essential operation in bonding is the breaking of joints. Stretchers and headers secure longitudinal and transverse bonding. In a good bond the various units are properly interlocked longitudinally and transversely so that the resulting work is self supporting and stable under loads. There are no continuous vertical joints in any two successive courses. See Fig. 69. The principal types of bonds in brick masonry are English, Flemish, Dutch, Raking and Herring Bone bonds.

(4) *Course* is a layer of masonry in which are bounded essentially stretchers and headers and a suitable backing when required. The thickness of a course is measured between two bed joints. Normally in brick masonry four courses are arranged in a foot as shown in Fig. 69. Usually the thickness of a course is not greater than that of the course below it.

(5) *Rubble* consists of stones of irregular size and shape but approximately cubical, being suitable for use in the construction of stone masonry. *Spalls* are also irregular sized chips of stone, which are usually angular and more or less flat. They are used for interior filling of walls and should be always placed vertical in a wedging fashion.

(6) *Quoins* are external corners of walls and are specially treated by using quoin stones to impart strength and appearance to a structure. Quoins may be of a different material than that used for the same walling. Quoins break the joints.

(7) *Closer Bricks*—King closer is a special sized brick with its one end half the width of the brick. See Fig. 67. They are used in the construction of splayed jambs and reveals. A full size brick is shown in Fig. 66.

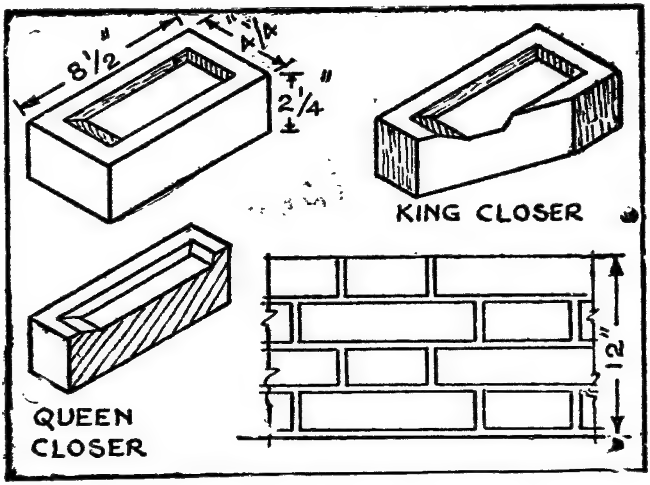


Fig. 66. Normal size of a full brick.

Fig. 67. A king closer brick

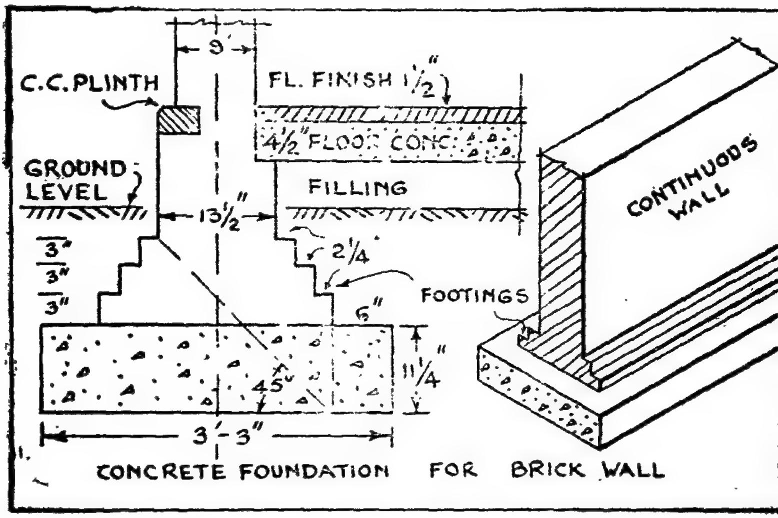
Queen Closer is a half brick having the length same as that of a full brick but width only a half at both ends. See Fig. 68. They are used to secure bond in brick work and are placed next to a quoin header.

Squint Bricks—These are corner bricks used for forming acute or oblique corners in brick masonry. Pieces of bricks are called bats. Bats less than the size of half brick are not usually permitted in good work.

(8) *Frog*—Bricks are provided with indentation marks called frogs on their flatter face to form a key for the mortar. Frogs also reduce the weight of bricks. They sometimes

carry impressions indicating the manufacture's name. A brick is laid in the wall with the frog uppermost.

Art. 54. Terms Used (*Contd*). (9) *Wall faces and Back fillings*—The external face of a wall or a structure is termed as *face*. The materials used for facing should be specially selected to withstand atmosperic weathering action and also to give the desired appearance to a structure. The internal surface of wall is termed as *Back*. In stone masonry and composite wallings the back is usually constructed of a material which is defferent from the facing.



Figs. 70 and 71 Wall footings

(10) *Hearting*—The interior section of a wall between the facing and the backing is termed *Filling* or *Hearting*.

(11) *Joints*—These are of mortar used for binding the units of masonry into a mass. *Bed joints* are so arranged that the pressure acts normal to their plane. *Side joints* are transverse to the bed joints and also to the face of the work.

(12) *Footings* are the offsets provided at the foot of a wall to widen the base area. These are necessary when the intensity of load on the wall is greater than the bearing resistance of

the soil. For brick work the footing projections are usually $2\frac{1}{2}$ ins. and those for stone masonry 3 ins. See Figs. 70 and 71.

(13) *Plinth* is the term applied to the horizontal projecting course or courses, at the bottom of a superstructure wall. See Fig. 72. The top of plinth is at the level of the ground floor, It is intended normally to protect the interior of a buildig at the ground floor from the rain water and frost. In

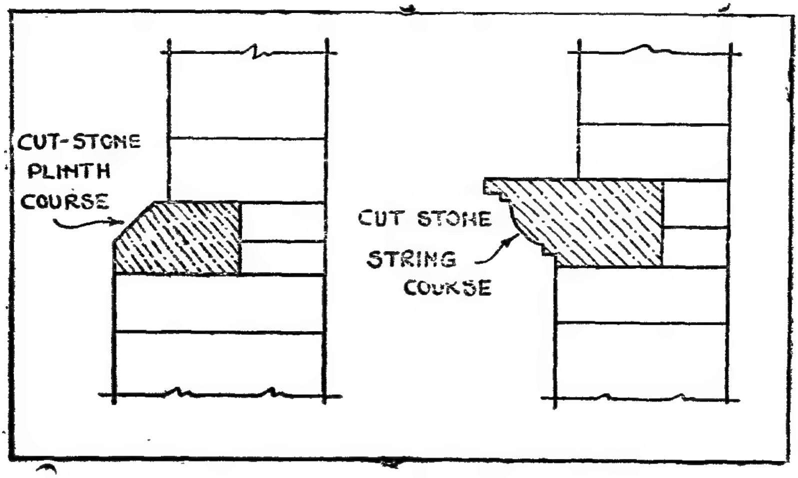


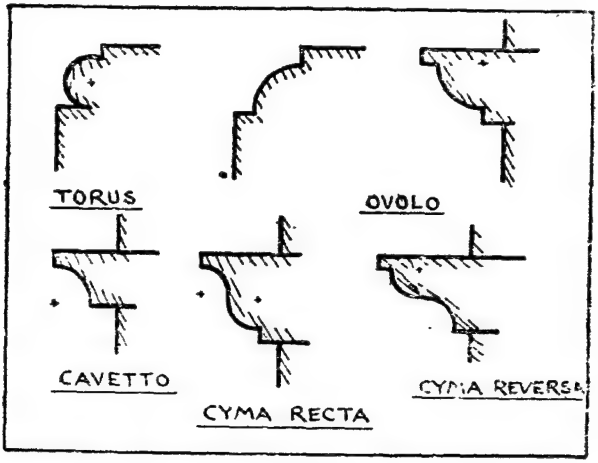
Fig. 72 Section showing cut stone plinth course, Fig. 72 Section showing cut stone string course.

superior and monumental work the topwost course of the plinth or the plinth course is often provided with heavy mouldings. The hight of the ground floor above ground is also termed as plinth. From the hygenic point of view a raised plinth or base is always an advantage. Note the location of plinth and plinth course above ground level in the above figure.

(14) *String Course* is a continuous horizontal course of masonry, projecting from the face of a wall, intended to throw off rain water at intervals of height. A string course may either be plain or moulded. See Fig. 73. String course also adds to the architectural features of a building and

also stregthen a weak wall. Though string courses are mainly located at floor levels; their use at window heights is not uncommon.

(15) *Cornice* is a projecting ornamental course or courses usually moulded to add to the appearance of a face work. A cornice is placed at the top of a wall or at the junction of wall and ceiling. The top part of an entamblature is termed as cornice.



Figs. 74 to 79. Different types of mouldings.

In Fig. 74 to 79 are illustrated different types of moulding suited to produce an architectural effect for the projecting courses in the face work of masonry, for use in plinth, string course, coping, eorbels etc.

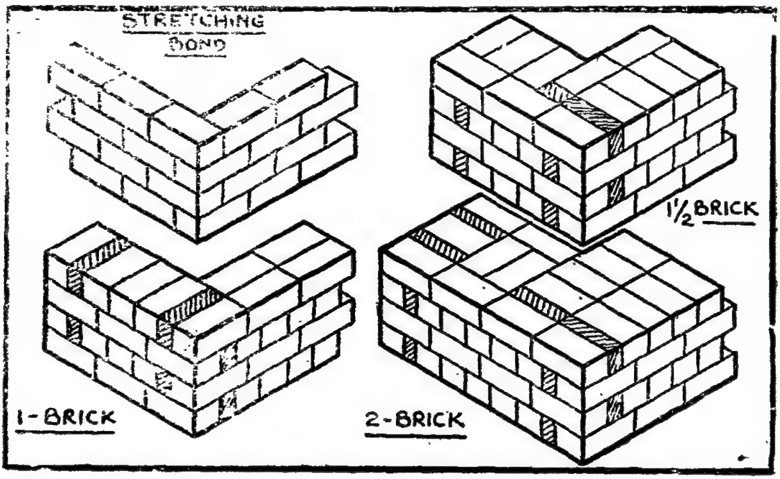
(16) *Stretcher Course* is one in which all the bricks are laid as stretchers. In walls thicker than one brick, a stretcher course is one which presents all stretchers on the exposed face.

Header Course is one in which all bricks are laid as headers.

In Figs. 80 to 83 are shown the uses of header and stretcher course in walls of different thickness.

(17) *Blocking Course*–The topmost course of stones or bricks placed on top of a cornice. Its object is to add extra weight to stabilise the projecting cornice and thus prevent it from overturning. It should therefore be selected of heavy units. A blocking course adds to the appearance of a building. A typical blocking course is shown in fig. 85.

(18) *Coping*—The exposed top of a wall is finished with a special course to prevent the entrance of rain water and moisture into the interior. If of stone, the coping masonry should be of heavier units, each extending for the full width



Figs. 80 to 83. Showing the use of headers and stretchers in walls.

of the wall and properly secured to one another and to the wall below by means of cramps and dowels, and laid in good hydraulic mortar or cement. The tops of copings are finished in several ways for the purpose of throwing the rain water off the face of the wall. To facilitate this, drip moulding is provided at the underside of the projecting portion. This device is commonly known as weathering and throating. See Fig. 84.

(19) *Corbel and Corbelled Course*—Corbel is a stone or brick projecting from a wall to provide a support, as in the case of wall plates for floors or for detached roofs. Corbels

should be sufficiently embedded in the wall. Brick corbels are formed by projecting headers by not more than $2\frac{1}{4}$ ins. each time beyond the lower ones. Corbels are also used to support the cornice. Sometimes a series of corbels are arranged to form a corbelled course. This method of construction is known as corbelling. See Fig. 85.

(20) *Jambs and Reveals*—Jambs are the vertical sides of doors and windows or openings in general showing the wall in thickness. They may be either square or splayed. Splayed jambs are better since they allow the shutters to be

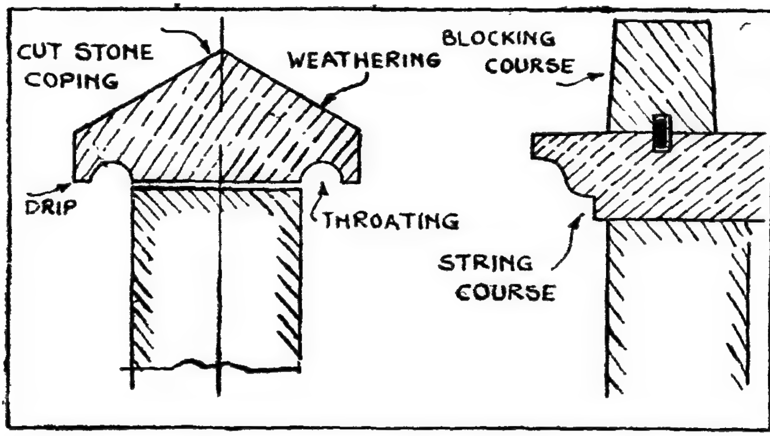


Fig. 84 Showing details of coping, Fig. 85. Blocking Course.

opened at an obtuse angle and thus allow more light to enter a room.

Jambs are provided with a recess or rebate to form a *reveal* for receiving a door or a window frame. The width of the reveal which is on the exposed side, is usually 3″ to 5″ and sometimes carries a moulding to improve the appearance. See doors and windows.

(21) *Parapet*—A low wall built round a terrace in the case of buildings with flat roofs or along the edge of the gutter at the eves of sloped roofs or in front of open verandahs. It is intended primarily to act as a fence wall

for persons moving on the terrace, but it also serves to improve the appearance of a building, in which case it may be finished in a decorative manner. A parapet may be of a solid wall or it may be of an open type with ballustrades and jali work.

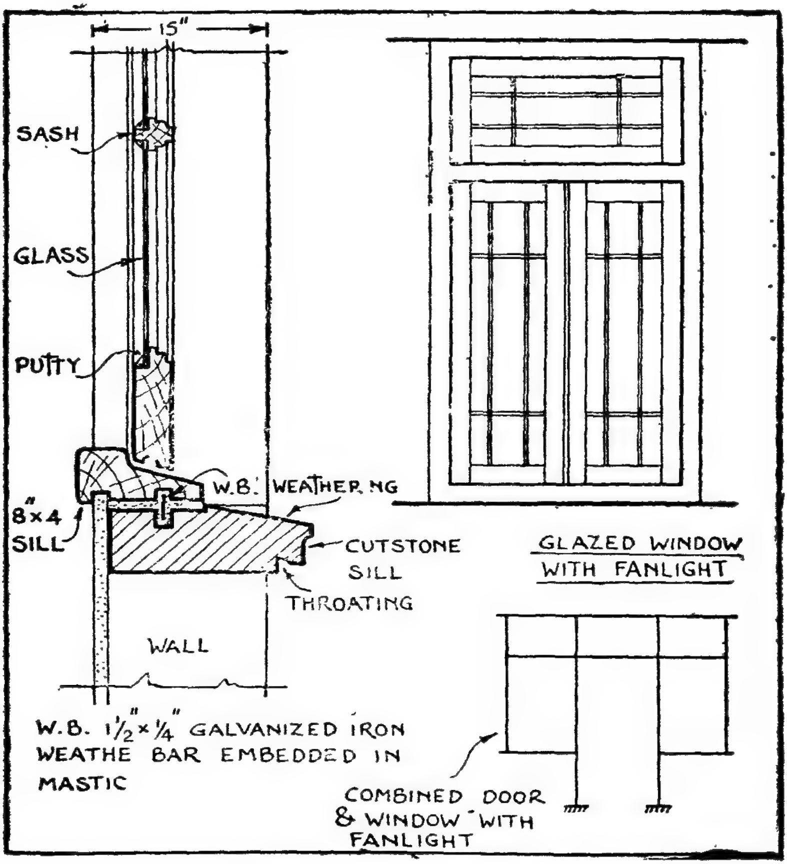


Fig. 86. Sills for windows.

(22) *Sills*—These are horizontal parts of opening for windows. They may be of cut stone or of concrete slabs and timber planks are also used as sills. When placed in external openings they must project beyond the face of the wall to throw off the water. See Fig. 86. A weather bar is provided between the sill and the wall on which it rests. It may be

noted that the bottom horizontal timber piece of a window or a door frame connecting the two vertical members, is also termed as "sill".

(23) *Setting out Rod* is a specially prepared piece of wood for marking accurately the number of horizontal courses to be built in a fixed height of a wall. A setting-out rod is approximately 26×2″×1″ scantling of the required length. It is very essential to control the vertical progress of a structure.

(24) *Buttress* is a projection from the wall intended to give strength at intervals along long walls. They have to resist a thrust for which their size is designed. A pinacle is often placed on the top of a buttress to add to its stability when used for walls in a building.

Art. 55 Dressing of Stone–Stone is removed from the quarry by blasting and wedging the blocks from the solid mass. Before it is sent out for building purposes, it is roughly worked or dressed in the quarry. It is then sent to the required place where it is subjected to some form of cutting for being put finally into the wall. Dressing is, in fact, the art of imparting an appearance of suitable character to the face of a stone and also includes its shaping to a proper size. Various implements and tools are used for dressing stones. The more commonly used ones can be classified as:-(i) Quarry hammers of different weights, (ii) Frame saw with a blade of chisel, (iii) Club and mash hammers (iv); Chisels of different sizes, and (v) Mallets.

The following is a brief description of the different types of dressings used in stone mesonry work:—

(a) *Rough or Quarry Dressing*–When a stone is obtained from a quarry, it is broken up into suitable sizes such as khandki, corners, headers, and rectangular blocks. Typical khandki stretcher and header stone are shown in Figs. 87 and 88. These are roughly dressed by means of quarry hammers. If the stone is soft it is cut into square blocks and slabs by a frame saw. Circular stone sections

for columns and pedestals are turned on lathes in a manner similar to wood.

(b) *Dressing and preparing a stone at Building site*—This consists of accurately squaring the face of a stone by chisels and hammers. Marginal grooves are cut for the purpose and the stone is worked on all the edges with respect to a fixed datum edge. The required widths at right angles to the face for the square bedding joints and side joints are also worked.

The operation of surfacing a stone on the exposed faces in general depends on the particular type of finish required in each case. In all surface operations, the aim is to reduce the irregularities of the surface of a quarry faced stone and to impart it a plane surface. To secure this marginal chisel drafts of about an inch width are cut and squared around the four edges of the stone. The enclosed space is subsequently worked. For a large face of a stone, subsidiary drafts are cut to ensure the accuracy of the work.

The different types of surface treatments for stone masonry work are illustrated in Figs. 89 to 92.

Chisel drafted margine—The general surface of the stone is left rough and a margin of one inch width is sunk about the four edges. See Fig. 89.

Tooled surfaces—Figs. 90 & 91 may be rough or fine pointed, but are often accompanied by chisel drafted margin.

Cut stone work has a surface dressed true with a sharp chisel as shown in Fig. 91. The chisel marks are hardly perceptible.

Rubbed Surface and Polished Surface are shown in Fig. 92. They are special varieties and are recommended where a smooth finish is required. One piece of stone is rubbed against another and if necessary, water and sand are added in the initial stage. To obtain a polished finish, grit alone or pumice stone may be used, and very often, if the work of

polishing is done with the aid of machine power, the results are found satisfactory in addition to quick work.

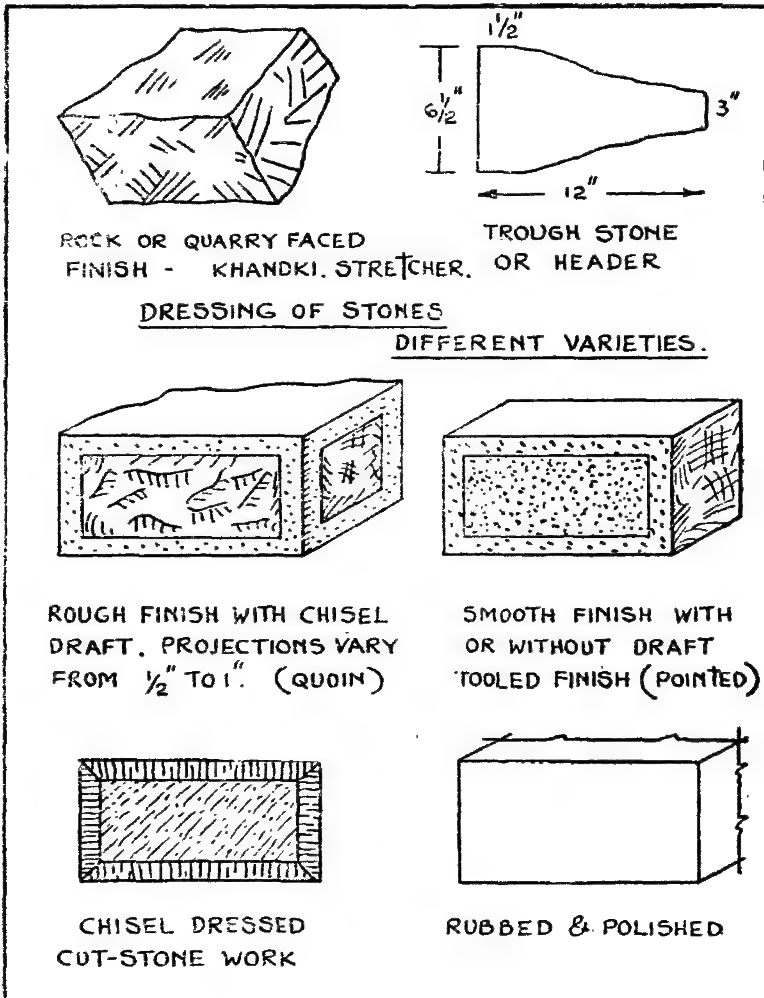


Fig. 41 and 88. Khadki stretcher and a through stone.
Fig. 89 and 92. Different types of stone dressings.

Art. 56. General Principles of Stone Masonry Construction—The following are the general principles to

be followed in order to ensure strong and durable stone masonry work:—

(i) Masonry may be constructed in cement mortar or lime mortar. Sometimes mud is also used as a binding material for the construction of masonry above plinth level. But for all underground construction where damp-proof qualities are required and for all acqueous foundations, good hydraulic mortar or cement should only be used.

(ii) *Natural Bed of a stone*—The dressing of a stone should be carried out so that when it is placed in a wall or in an arch, the pressure coming upon it should be at right angles to its natural quarry bed, *i. e.*, the surface on which they were lying before being quarried. Only good variety of stones should be selected.

(iii) *Breaking of Joints*—Care should be taken to avoid the formation of continuous vertical joints in a wall face. No two vertical joints should come one over the other in any two consecutive layers. By this principle, each stone is well bonded in a wall which thus becomes strong enough to receive load. For rubble work, the breaking of joints should be specially attended to.

(iv) *Through Stones or Headers*—to connect the two face of a wall,—the facing and the backing,—and thus add to its transverse strength; a sufficient number of through stones or headers must be introduced in the wall. They should be well distributed in the whole wall by arranging them in a staggered fashion in successive courses. The spacing of headers in the same course should not exceed 3 to 4 feet.

(v) The faces of walls should be constructed truely vertical or true to any batter if this is specified. Plumb rule and wooden templates should be used to ensure this.

(vi) The masonry in the entire lengths of walls in a building should be raised uniformly. If it is necessary to raise any part of a wall in advance, proper toothing must be formed by giving projections to bond to the wall to be built later.

(vii) It should be remembered that when any particular kind of stone is selected, the strength of ashlar masonry depends more upon solidity and dressing of stones, while that or rubble work depends upon the strength of mortar and compactness of interior filling of walls, or in general on the quality of workmanship.

In rubble masonry wherever required, chips should be used and inserted vertically for interior filling. The use of feather edged stones in the face work should never be allowed.

(viii) The work should be kept wet until the mortar sets and becomes hard. The watering period varies from 15 to 21 days. Stones should also be wetted before they are placed in a wall, as otherwise a dry stone absorbs moisture from the mortar and thus weakens it.

(ix) When solid bedding of a stone is specified, great care should be taken to see that the bed joint are not dressed hollow. The effect of such a hollow bed joint is shown in Fig. 106. In rubble masonry work, the bed joints should be at least 1½ ins. to 3 ins. in depth as otherwise, the edges of stones will fail along the face, as shown in fig. 109. Chips and spauls should never be permitted in the bed joints for setting a stone.

(x) As far as possible the load should act axially and centrally on masonry sections. If non-axial or eccentric loads and oblique loads have to be supported by masonry, every precaution should be taken to see that there are no resulting tensile stresses in any section in the masonry.

(xi) Joints are weak points in masonry and on exposed faces they should be throughly protected from the ravaging effects of atmospheric agencies, by proper pointing with cement or good hydraulic mortar.

Art. 57. Classification of Stone Masonry Work— The two principal classes of stone masonry work are—

(i) Ashlar Masonry; and (ii) Rubble massonry.

The following is a brief description of construction of

these two classes of stone masonry with their modified varieties as used in different types of stone wallings.

(i) *Ashlar Masonry*—Ashlar masonry consists of finely dressed and regular shaped blocks of stones. The courses are usually thicker, being seldom less than 10 to 12 ins. But deeper courses are often used in heavy plinths and monumental work. Ashlar masonry is too costly to be adopted for the

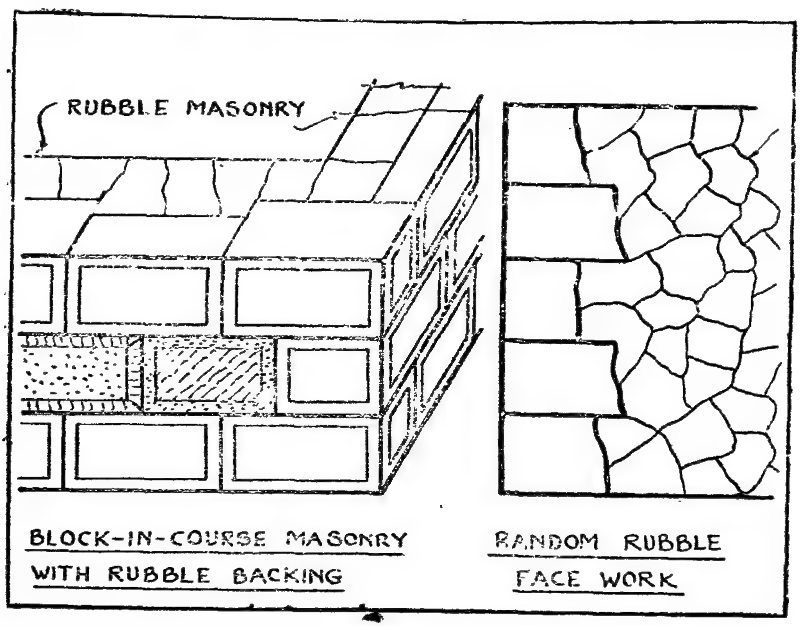


Fig. 93. Ashlar masonry. Fig. 94 Random rubble face work.

entire thickness of the wall and hence it is used mainly for the face work, the backing being filled in with rubble of brick work. As stones are regular blocks the joints in ashlar work are uniform and seldom exceed ½" in thickness. See Fig. 93

Ashlar masonry is classified on the type of dressing adopted for surface finishing, as,–plain or fine ashlar, rough tooled ashlar, and chamferred ashlar. Ashlar masonry is generally built in courses. When it is not built in regular courses, it is called random ashlar.

Block-in-Course is the name applied to a variety of ashlar where heavy type of masonry is required as in embankment walls, harbour walls, piers and abutments of bridges, etc. The courses are deep and the face is usually hammer dressed or rough tooled as specified, with or without chisel draft.

Art. 58 (ii) **Rubble Masonry**—A rubble wall is built of smaller sized stones which (a) may have a rectangular face to form course rubble, or (b) may have irregular shapes to have uncoursed and random rubble.

(a) *Conrsed Rubble Masonry*—The stones used in rubble masonry are not solid rectangular blocks as in the case of ashlar masonry, or brick masonry. Hence bonding and breaking joints cannot be done quite perfectly and uniformly. Rubble walls are therefore weaker and require to be normally thicker. They consume a greater quantity of mortar proportionately and their strength depends greatly upon the strength of the mortar and the quality of workmanship. Precautions should be taken in the construction of rubble walls to avoid any hollow space in the interior due to bad workmanship.

Face Stones of Khandki—For the face stones, the bed joints should have a solid bedding of at least $1\frac{1}{2}$ in. from the face, and the side joints should be solid to a depth of at least 1 in. Each face stone should tail into the wall to a sufficient depth to ensure through bonding.

In Fig. 95 is illustrated an isometric view of a coursed rubble masonry wall in three courses. Note the khandki facing and rubble backing with the hearting of small sized stones in between them. The locations of quoins and headers are clearly indicated in the figure.

Through stones, Bond stones or Headers should be used at a spacing of about 3 to 5 feet, as already stated. Care should be taken to see that they are not placed one above the other in successive courses. For walls of upto $1\frac{1}{2}$ ft.

thickness, a through stone should extend from one face of the wall to other; but for walls of greater thickness overlapping headers forming a stone joint should be used.

Corner Stones or Quoins—At the external angles of walls corner stones or quoins are built to give strength and appearance to the wall. Ordinarily they are of the same thickness as that of the course. But for massive work they are selected from heavy stones, hammer dressed and chamferred. Quoins are worked to show two sides and as they have no lateral support, their beds must be dressed square

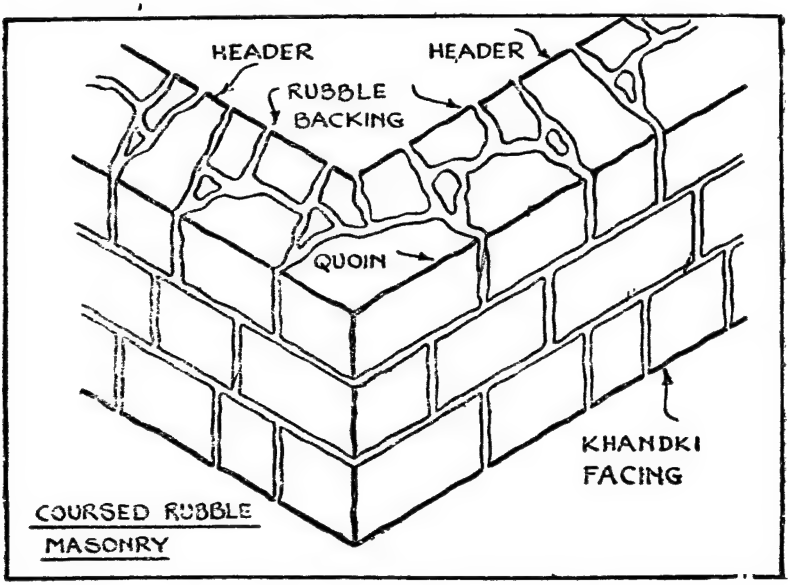


Fig. 95, Coured rubble masonry wall

at least 4 ins. from the face to afford them the necessary stability.

To secure the breaking of vertical joints, one of the two sides is longer than the other and quoins are placed alternately with their longer and shorter sides along the same face of the wall in successive courses.

Art. 59. Uncoursed and Random Rubble Masonry. (i) *Square Faced Uncoursed Rubble*—The second-variety of rubble masonry in which square faced stones are used is shown in Figs. 96 and 97. The stones need not be of the same height as that of the quoins nor are there any regular courses of stones of the same height as in the case of coursed rubble masonry described in Art. 58. Square faced uncoursed rubble can be built to course so that in Fig. 96 it may be noted that 2nd, 3rd and 4th quions are all included in one course. At the top of these courses which are usually of 1 to 2 feet in height, the masonry is levelled up before

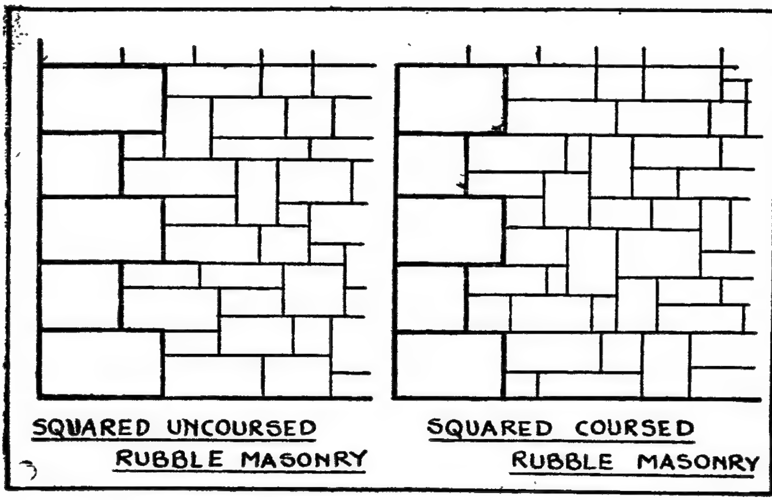


Fig. 96. Squared uncoursed rubble masonry

Fig. 97. Squared coursed rubble masonry.

the top course is laid. This type of work is cheap as it allows the use of small sized stones, and is used for unimportant buildings. Uncoursed rubble masonry can be also built with irregular faced stone for very cheap constructions as in the case of compound walls and out-buildings, etc.

(ii) *Random Rubble Masonry*—The face stones of this class of masonry have no regular shape. For superior work a fairly uniform size and shape of stones are used for the

face work. See Fig. 95. It is necessary that the face stones should tail back sufficiently into the hearting for proper bondage. In Figs. 98 and 99 are shown the two types of random rubble masonry walls which are used where great strength and solid construction are not in demand.

Art. 60. Methods of Secusing Heavy Stoner to be Lifted—Ordinary heavy stones are lifted by means of roap or chain passing round them and with the help of poles two or more people are employed to lift them. This is a rough method and is not suitable for finely dressed heavy

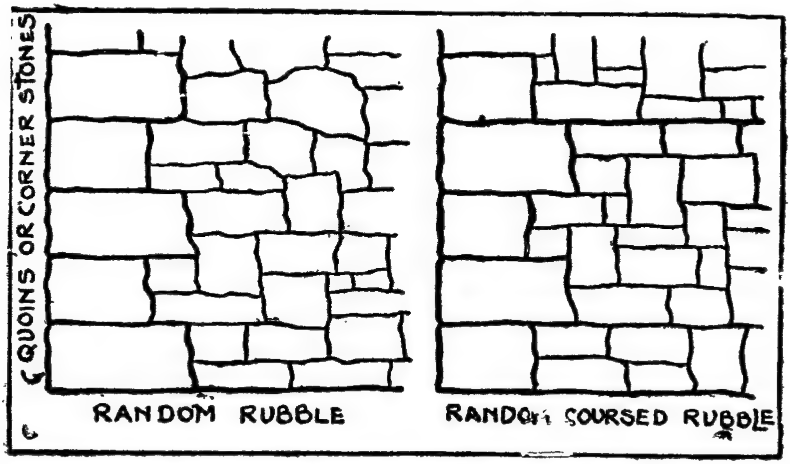
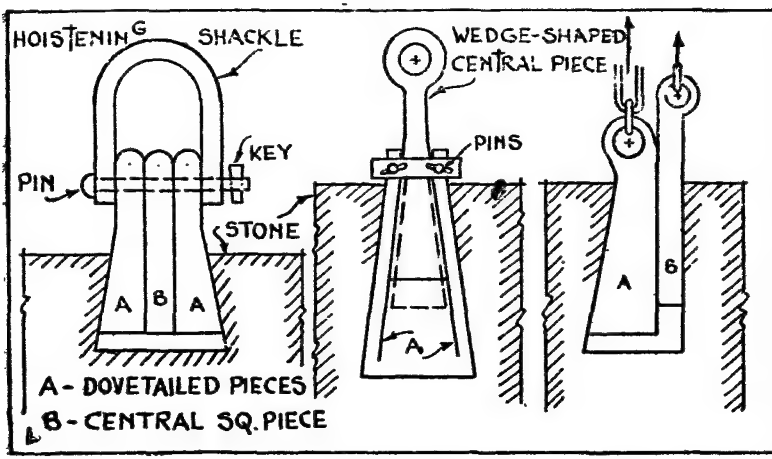


Fig. 98 and 99. Random rubble masonry.

stones with mouldings on their faces particularly when they are of a softer variety. They require to be lifted and hoisted with great care for being placed in their final position in the wall. In the following figures are illustrated some of such devices.

(i) *Lewis or Lewises*, is an appliance which fits in the tapered hole cut in the top of the stone. The lewis in Fig. 100 is suited for heavy stones and carries two dovetailed pieces A–*A* and a central rectangular piece *B*. *A-A* are first intserted in the hole and then the piece *B*. The three are then secured to a hoistening ring by means of a pin and a



Figs. 100. 101, and 102 Different types of Lewises.

key. Another lewis is shown in Fig '101. The central piece is wedge shaped and can slide through frame *A–A*. In the drawn position while lifting the central piece presses against the two sides A-*A* of the frame, and prevents the lewis from being drawn out. This is very quick in operation either to set it in the stone or to remove it.

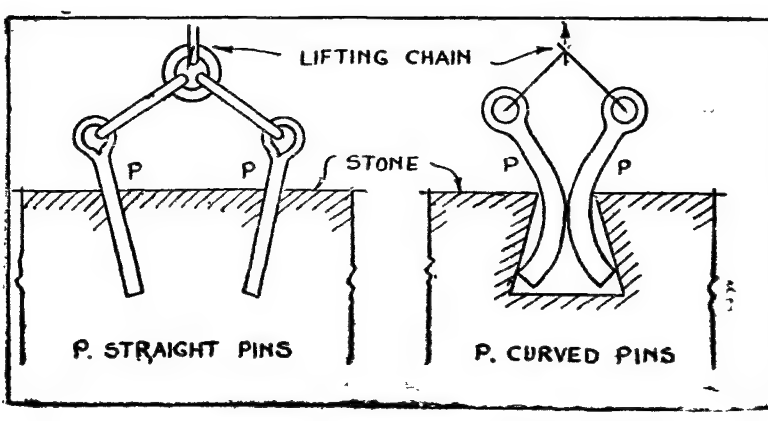


Fig. 102 Pair of Pins, Fig. 104. Pair of Curved Pins.

The lewis shown in Fig. 102, is a modified simple form of the lewis shown above. Its action can be easily followed from the figure. The pull is applied to the ring of *A*, and not to *B*

(ii) *Pair of pins*—The two pins *P-P* shown in Fig. 103 offer a very simple lifting device. On account of their being inserted in an inclined position into suitable holes made in the stone, the pins exert a grip on the stone when they are being pulled to raise a stone.

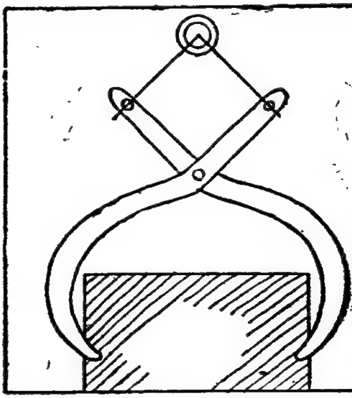


Fig. 105. pair of nippers.

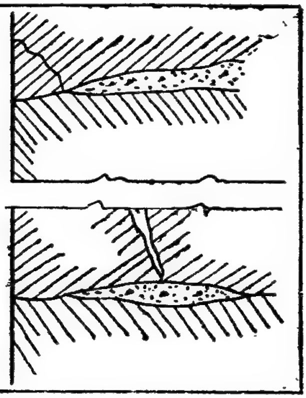


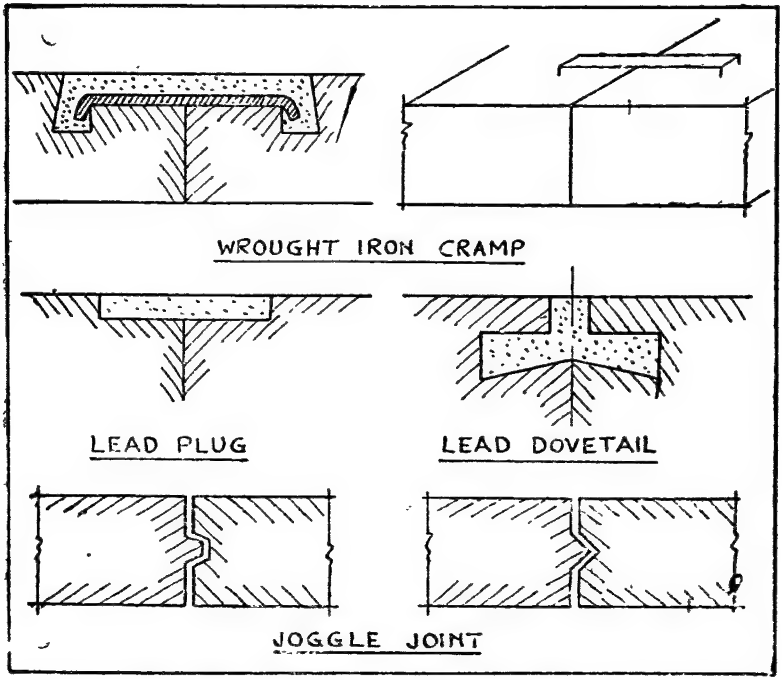
Fig 106 and 107. Defective construction in stone masonry work.

A pair of curved pins fitting in a dovetailed hole in a stone is also shown in Fig. 104, and serve the same purpose.

(iii) *Nippers*—Another device for lifting stones in the form of nippers is shown in Fig. 105. The points of nippers fit in the notches cut in the sides of the stone.

Art. 61. Use of Joggles, Dowels, and Cramps in Stone masonry—Heavy stones are kept from movement in a wall by the use of dowels, cramps and lead plugs or joggles. The dowels should be of copper, bronze or slate and should be set

in cement mortar. Ordinarily iron cramps oxidise and cause splits and discolouration in masonry. They are shown in Figs, 108 to 113. The stones used in coping, cornice and



Figs. 103 to 113. Joggles, dowels and cramps.

blocking course, etc, require special fixing between themselves and the supporting masonry by the above devices.

CHAPTER VI

Brick Masonry

General Principles of brick masonry construction. Bonds in brick work,-- English bond. Flemish bond, and other types of bonds. Bonds in pillar masonry and footing. Hollow walls and Cavity walls. Fire-place openings.

How to construct brickwork. Thickness of brick masonry walls. Stresses in brick masonry. Axial and oblique loads: Wind pressure on walls. Buttresses.

Art. 62. General Principles of Brick Masonry Construction—While studying the principles and methods of contruction of stone masonry walls in the previous chapter, references were also made to brick masonry and the common terms used in its connection. In this chapter, a detailed consideration regarding the various types and methods of construction of brick masonry will be explained.

In addition to the general principles mentioned in Art 56, the following ones are of importance for brick masonry:–

(i) Only good, well burnt bricks of regular shape, and manufactured from selected clay should be used. The use of small sized bricks should be avoided except when it is required to secure bond.

The common size of a brick is $8\frac{3}{4}$ in. x $4\frac{1}{4}$ in. x $2\frac{1}{2}$ in; but when built into a wall its size may be taken as 9 ins. x $4\frac{1}{2}$ ins. x 3 ins. including mortar joints. See Fig. 66.

(ii) Bricks should be thoroughly soaked in water before they are placed in masonry. The stopping of the air bubbles from a brick after it is placed in water indicates that it is properly soaked.

(iii) Bricks should be bonded well in the wall by one of the standard methods given in the following articles, so that the resulting masonry is structurally sound.

(iv) Unless the bricks are of a perfect durable quality to withstand the distructive effects of atmosphere, every exposed face of brickwork should be coverd by rendering coat of plaster. Otherwise the joints only could be solidly filled and pointed.

Art. 63. Bonds in Brick-Work—If bricks are laid in a wall without any care and in an irregular fashion, the resulting wall would lack in cohesion and fail under loads, as pointed out in the last chapter, under 'bond'. Therefore it is essential to lay the bricks in a systematic manner in a wall. Also regular methods that are more mechanical in nature, facilitate speedy construction. This is possible due to uniformity of shape of bricks and certain standard systems can be laid down for the laying of bricks in a wall to secure good bonding.

It should be remembered that the bonds in which more stretchers are used, imparts proportionately a greater longitudinal strength, whereas the use of more headers imparts transverse strength to a wall.

The fundamental bonds used in practice for constructing walls in general, are—

(*a*) English Bond; and (b) Flemish Bond.

In the following articles is given a brief description of these two types of bonds.

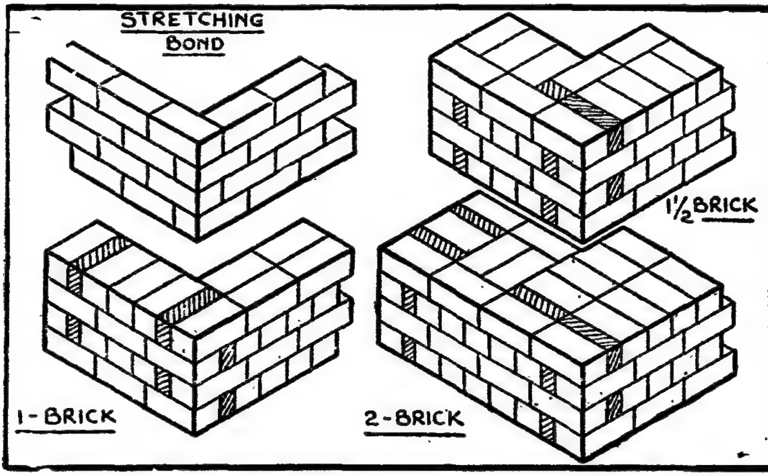
Art 64. Bonds in Brick work (Continued)—(*a*) **English Bond**—(i) The courses consist alternately of headers and stretchers.

(ii) The bond commences from the quoin or the stopped end in a wall, with a header, and a closer brick is placed immediately next to the above header. This is followed by a succession of headers on the same face in the same course.

(iii) In walls which have an even number of half bricks in thickness, the course which shows headers on

the face also shows headers on the ·back. Conversely, a strecher course on the face will also show stretchers at the back.

(iv) In walls which have an odd number of half bricks in thicknes, :a course which shows headers on the. face shows stretchers on the back, and stretchers on the face show headers on the back.



Figs. 114 to 117. English bond for ½; 1; 1½; and 2 brick walls.

(v) The bricks in the interior of thicker wall are not laid as stretchers; but they are laid as headers. This prevents formation of straight vertical joints in the heart of masonry. Thus for thicker walls more headers are used than the corresponding number of stretchers. This difficiency of stretchers results in the weakening of masonry longitudinally, and is overcome by the use of diagonal bond in the interior.

Figs. 114 to 117 show the English bond for ½; 1, 1½ and 2 brick walls. The locations of closer bricks are indicated by hatched lines. In Fig. 118 is shown the method of construction of 2½ brick wall according to English bond.

(b) **Flemish Bond**—A Flemish bond has the following aspects of construction.

(i) Each course represents headers and stretchers alternately.

(ii) Every alternate course commences with a header at the corner and is followed by a closer as in the case of English Bond. But a stretcher is placed next to this closer brick which is then followed by header and a stretcher alternately.

(iii) The centre of the header should be on the centre line of the stretcher in the course below it.

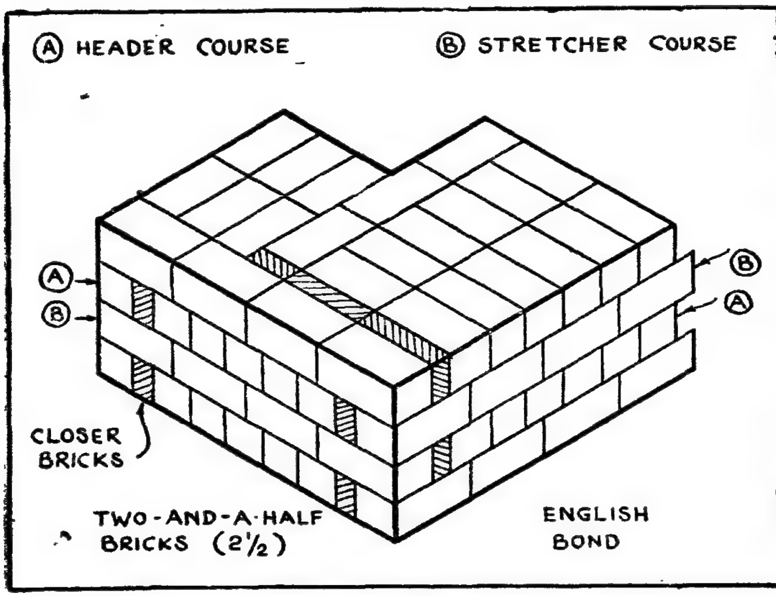


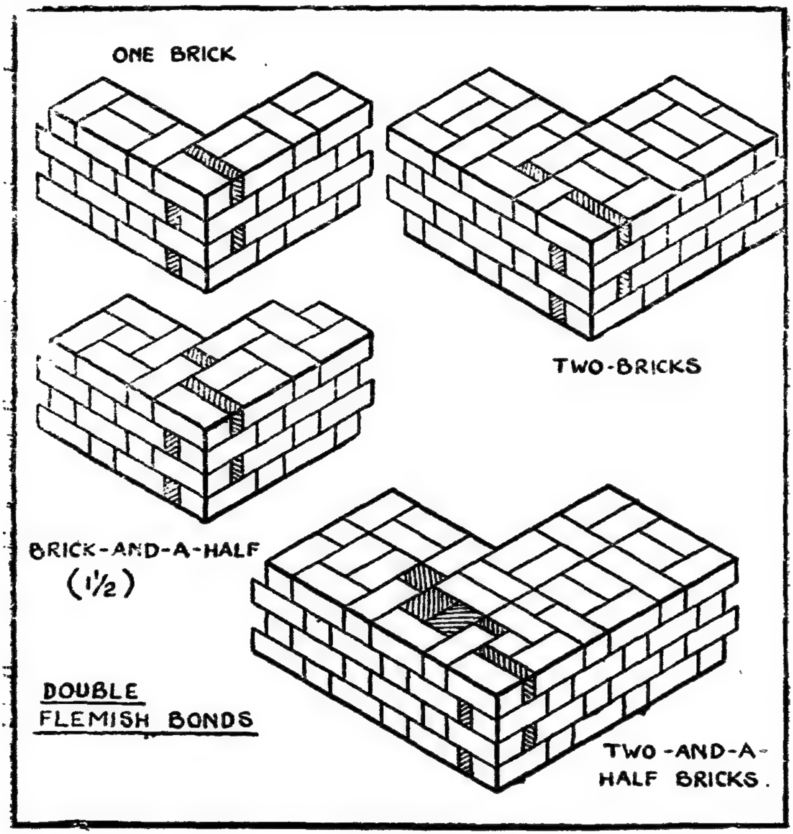
Fig. 118. English bond for $2\frac{1}{2}$ brick walls.

(iv) In the same course, the headers and stretchers on one face should come opposite headers and stretchers on the other face, except in the case of a "three half brick" wall, where alternate joints in the sectional bond are stopped by a stretcher.

The Figs. 119 to 122 indicate the arrangement of bricks in the Flemish bond for walls of different thickness. Single flemish bond for $1\frac{1}{2}$ brick wall is shown in Figs. 123 and 124. The use of false headers on the external faces give the

appearance of a Flemish bond. On the inside, header and stretcher course are used alternately as in an English bond.

It may be noted that Flemish bond admits of the use of a greater number of bats and hence is claimed to be economical.



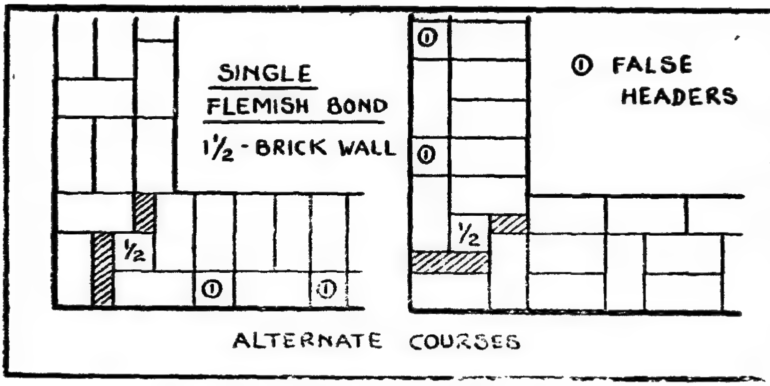
Figs. 119 to 122. Flemish bond for 1, $1\frac{1}{2}$, 2 and $2\frac{1}{2}$ brick walls,

English bond is stronger than Flemish bond for walls thicker than $1\frac{1}{2}$ brick. But for walls of 1 or $1\frac{1}{2}$ brick, the two bonds have practically equal strength.

It is claimed that Flemish bond is better in appearance, and thus sometimes, thick walls are constructed with a

facing of Flemish bond and a backing of English bond. This system combines the strength of the English bond with the appearance of the Flemish bond.

Art. 65. Other Types of Bond—In addition to the two principal types of bonds detailed in the previous articles, the following are the other types of bonds which are also used.



Figs 123 and 124. Single Flemish Bond.

(i) *Stretching Bond* is the one where all brick are laid as stretchers. See Fig. 125. A half-brick wall is built in this bond. It is also used for building brick-on-edge patition walls. The stretching bond is also termed as "running bond."

(ii) *Heading Bond* is the type where all bricks are laid as headers. See Fig. 126. Along the face of the wall, the longitudinal bond has only a lap of 2¼ ins. This bond is followed in footing courses.

(iii) *Garden Wall Bond*—Garden walls have to present both the faces and at the same time have to be of a greater longitudinal strength owing to the absence of cross wall at intervals. For economy, they are only of one brick thickness. It may be noted that usually a single brick wall presents one face only; and hence special bonding which is a slight modification of English and Flemish bond is used. Also a

stretching course has the advantage of showing a true face on both the sides.

Thus an *English Garden Wall* consists of one heading course to three or five stretching courses. The heading course

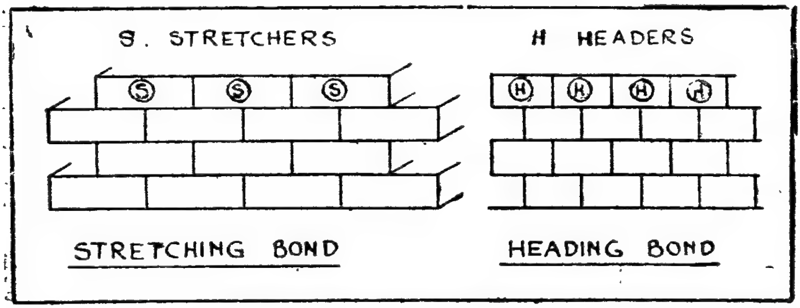


Fig. 125 Streching bond. Fig. 126. Heading bond.

is laid in specially choosen bricks of uniform length from the bricks avilable at the site. See Fig. 127.

(iv) *Flemish Garden Wall*—In this bond every alternate header of the header course in the English Garden Wall is

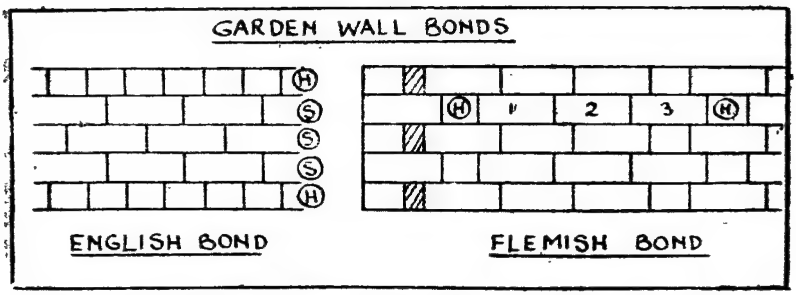


Fig 127 English Garden Wall bond.

Fig. 128. Flemish Garden Wall bond.

replaced by a stretcher to incorporate the principles of Flemish Bond. In addition sometimes a header is introduced after every three or four stretchers in the stretcher courses. See Fig. 128.

(v) *Raking Bond*—It is already remarked that in walls which are more than two-brick in thickness the longitudinal bonding is weak, on account of header being used for interior

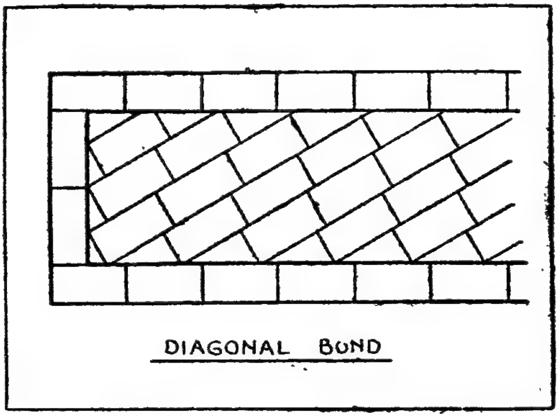
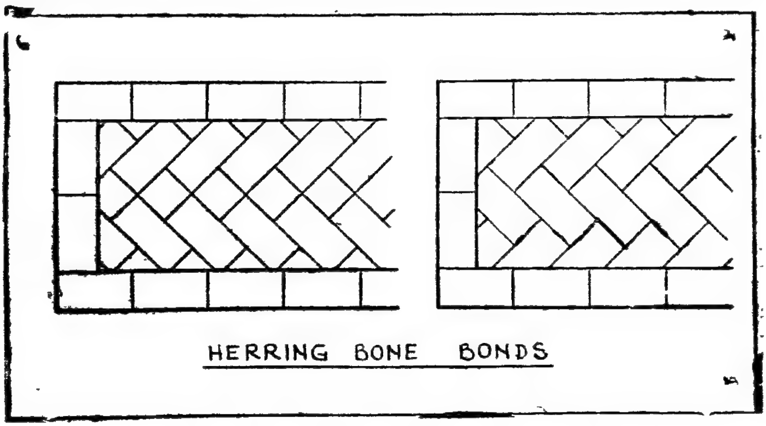


Fig. 129. Raking bond. Diagonal type.

filling. This defect is overcome by using a diagonal bond and placing the bricks oblique to the face of the wall, every



Figs. 130 and 131. Herring bone bonds.

alternate or every fourth course. Raking bond can be either diagonal or herring-bone.

In the *Diagonal Bond*, the bricks are laid in a row from face to face of the wall. See Fig, 129; whereas in the *Herring bone*

Bond, this inclination is changed at the centre of the wall in the same courses. See Figs. 130 and 131. Herring bone bond is suitable for very thick wall. Both the types of raking bonds require the extra cut pieces of bricks since the trangular space at the ends require to be filled up by small pieces.

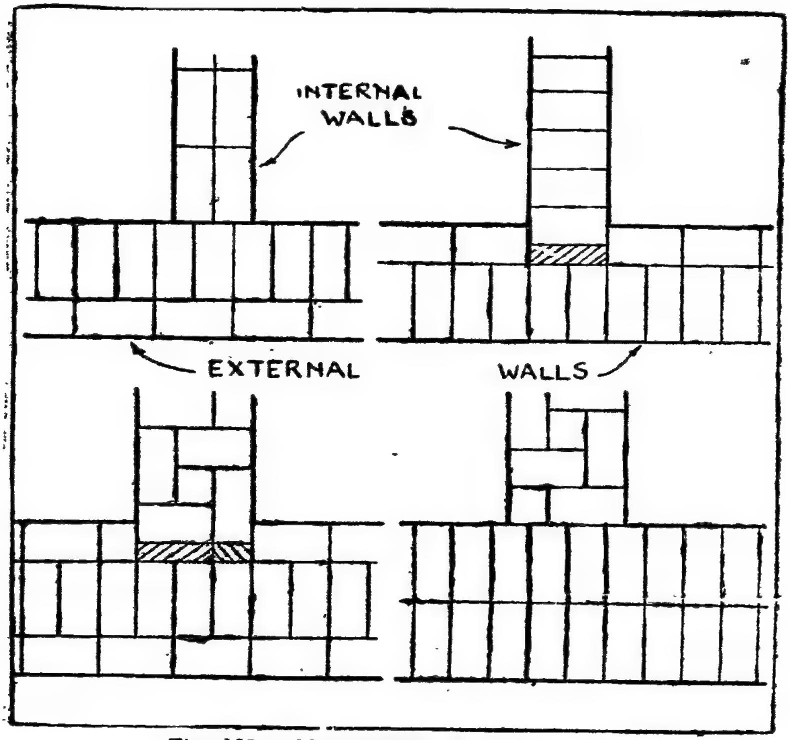
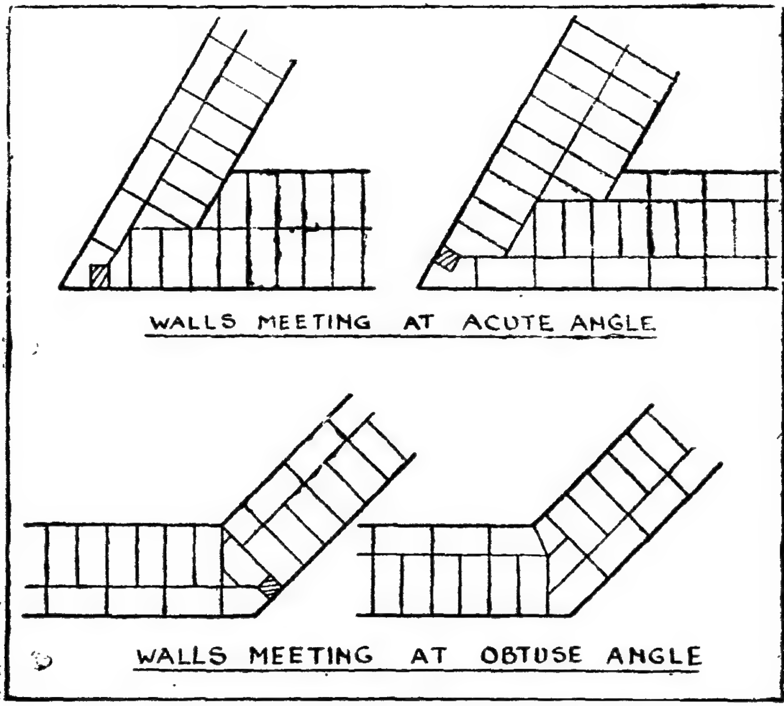


Fig. 132 to 133. Bonding of internal and external wall meeting at right angles.

Art. 62. Other Types of Bonds (Contd.)

(i) *Bonds at the intersection of walls*—Walls meeting at right angles. When two walls intersect as in the case of an internal wall, no staight vertical joint should be left between the two walls. The internal wall should have a bond of $2\frac{1}{4}$ ins. with the main wall in each alternate course See Figs. 132 to 135.

(ii) *Walls meeting at Acute or Obtuse Angles*—The types of bonds suitable for these two angles respectively are shown in Figs. 136 to 139. When the walls meet and form an angle, a wedge-shaped closer next to the quoin

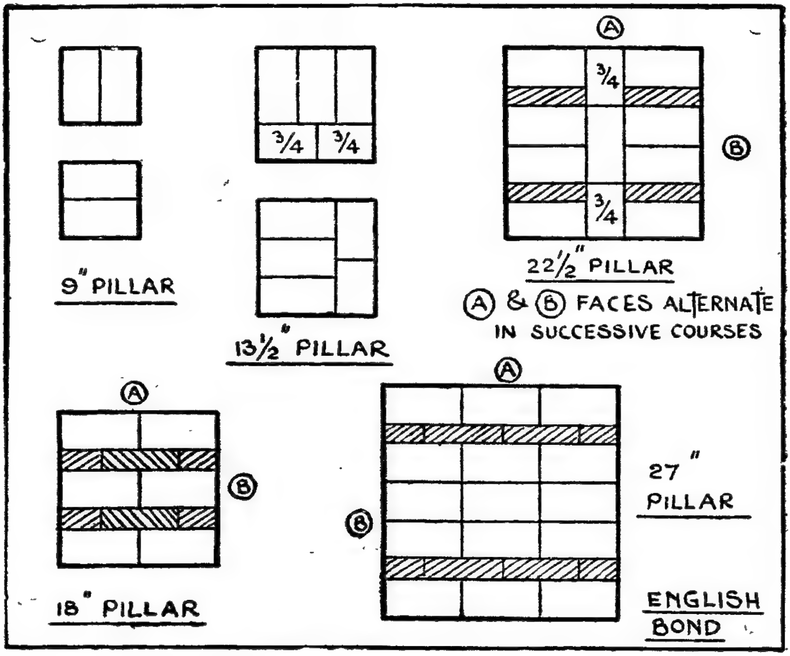


Figs. 136 and 137. Walls meeting at an acute angle,
Figs. 138 and 139. Walls meeting at an obtuse angle.

header is used; and to form an obtuse angle a special squint quoin brick of the required angle is used. The side angle is formed with a special interior angle brick.

Art. 67. Bonds in Pillar Masonry—The bonding of bricks in square pillars, in English and Flemish Bonds is shown in Figs. 140 to 146 and 147 to to 150 respectively. One course is shown with its face marked "A". The next oourse is laid on it so that the face marked "B" lies alongside the previous face marked "A".

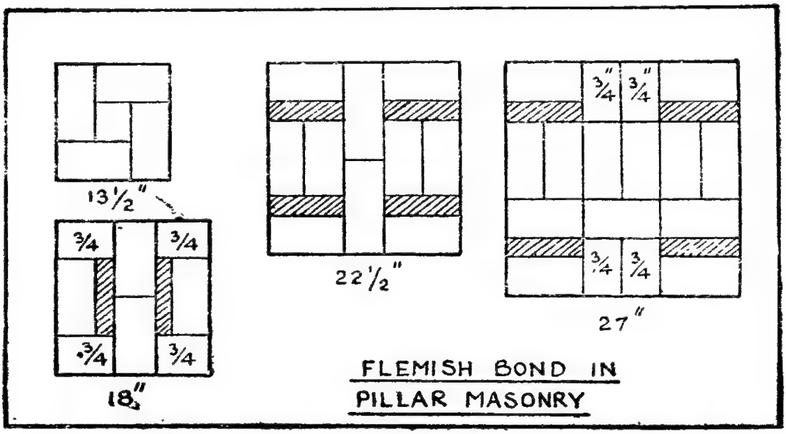
Art. 68. Bonds in Footing Masonry—At the foot of walls where they rest on a concrete foundation, the brick work is spread out to form footings for extending the base of the wall. Each footing extends ½ inch which is termed offset. Figs. 151 and 152 explain the bond suited in footing. All bricks projecting out are laid as headers.



Figs. 140 to 146. Pillar masonry English bond.

Art. 69. Bond In Simple Hollow Walls—Hollow walls are often constructed by the use of stretchers and headers in each course laid on edge. See Figs. 153 to 156. H and S indicate headers and stretchers respectively. It is often recommended that all corners and sides of opening, solid masonry to a distance of one brick should be built. A suitable reinforcement such as binding wire, B. R. C. fabric, expanded metal or galvanized strips, is used to strengthen hollow walls at every alternate or fourth course. The use of hollow walls is very common in framed structures.

Art. 70. Cavity Walls (i) *Purpose*—In place where buildings are exposed to extreme weather conditions, external walls are constructed in two sections with a vertical cavity of about 2″ to 3″ wide in between. Such hollow walls have several advantages. The outer section acts like a covering, which together with the adjacent cavity prevents moisture from penetrating into the inner section. The rooms of the houses are thus kept free from damp conditions. The air

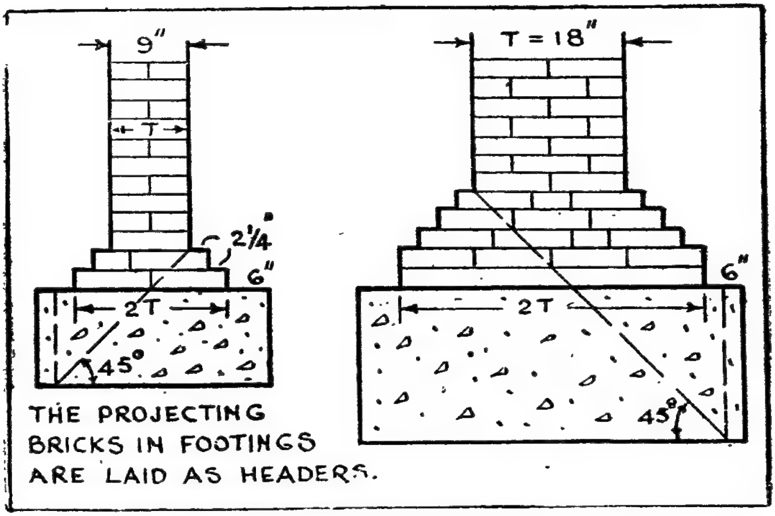


Figs. 147 to 750. Pillar masonry. Flemish bond.

in the vertical cavity affords insulation in the rooms against outside atmospheric changes and acts like a sound insulater also.

(ii) *Bond and Constrnction Details.* The usual practice to construct these walls is to provide a thickness of 9 ins. for the inner section and 4½″ for the outer. The cavity between the two gives very good results for a thickness of 2¼ inch. The top of the two sections of the walls is built solid for supporting the upper floor of the roof.

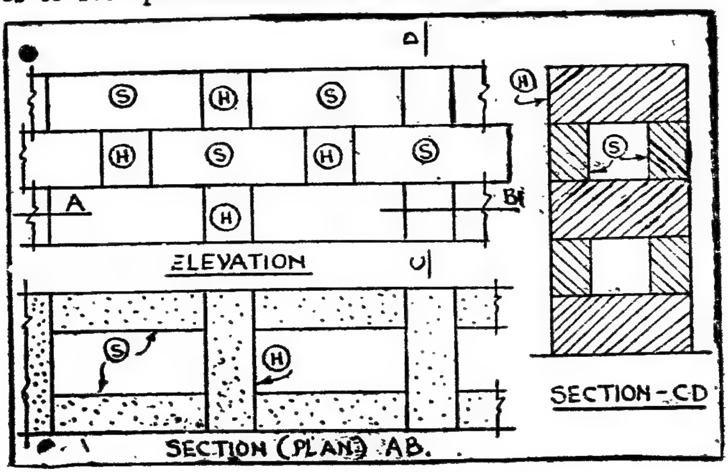
The two sections should be tied together by lateral ties to afford the necessary transverse strength. The ties are placed at 3 feet intervals horizontally and at 1′—0″ interval vertically. They are either of vitrified bricks spe-



Figs. 151 and 152. Bonding of bricks in footings.

cially moulded for the purpose or of galvanized iron of a suitable design. See Fig. 156 for various construction details. In Fig. 157 is shown the method of construction at the tops of openings.

Air bricks are provided near the base and below the eves to set up circulation of air for ventilation. At the



Figs. 153 to 155. Single hollow wall construction.

bottom of the cavity a coving of cement is made to drain away the water, if collected, through weep holes provided at intervals. At all openings in such walls care should be

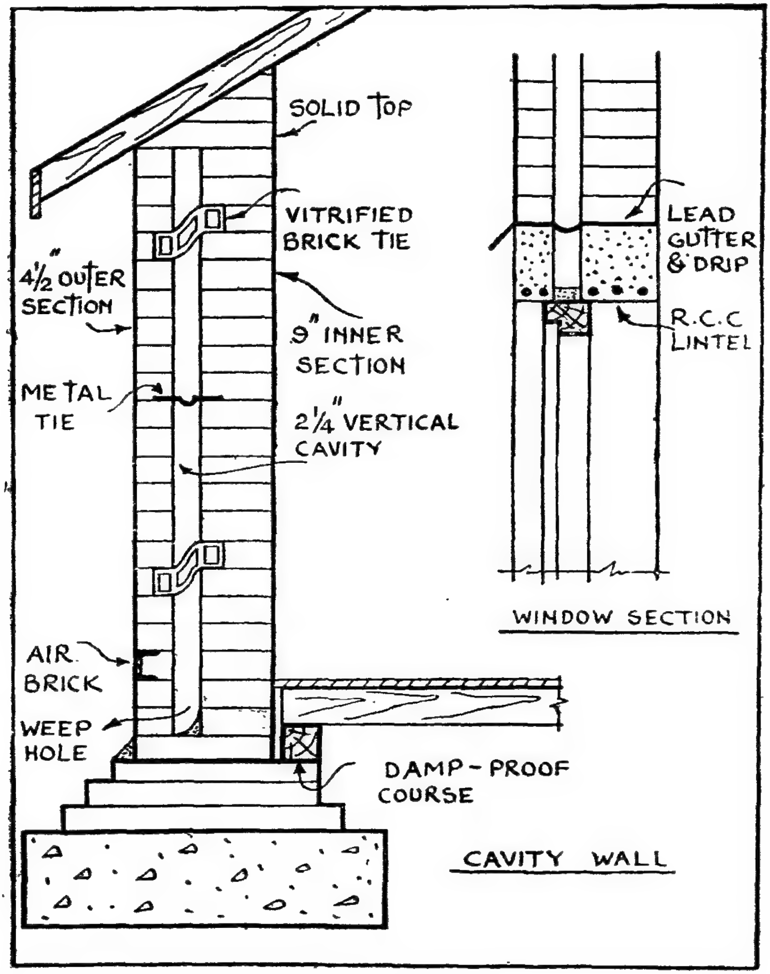


Fig. 156, Cavity wall construction. Fig 157. Cavity wall at the openings.

taken to prevent the entrance of moisture. The brick work should be built solid around the opening and a thick barrier of a damp proof material such as slate or lead should be

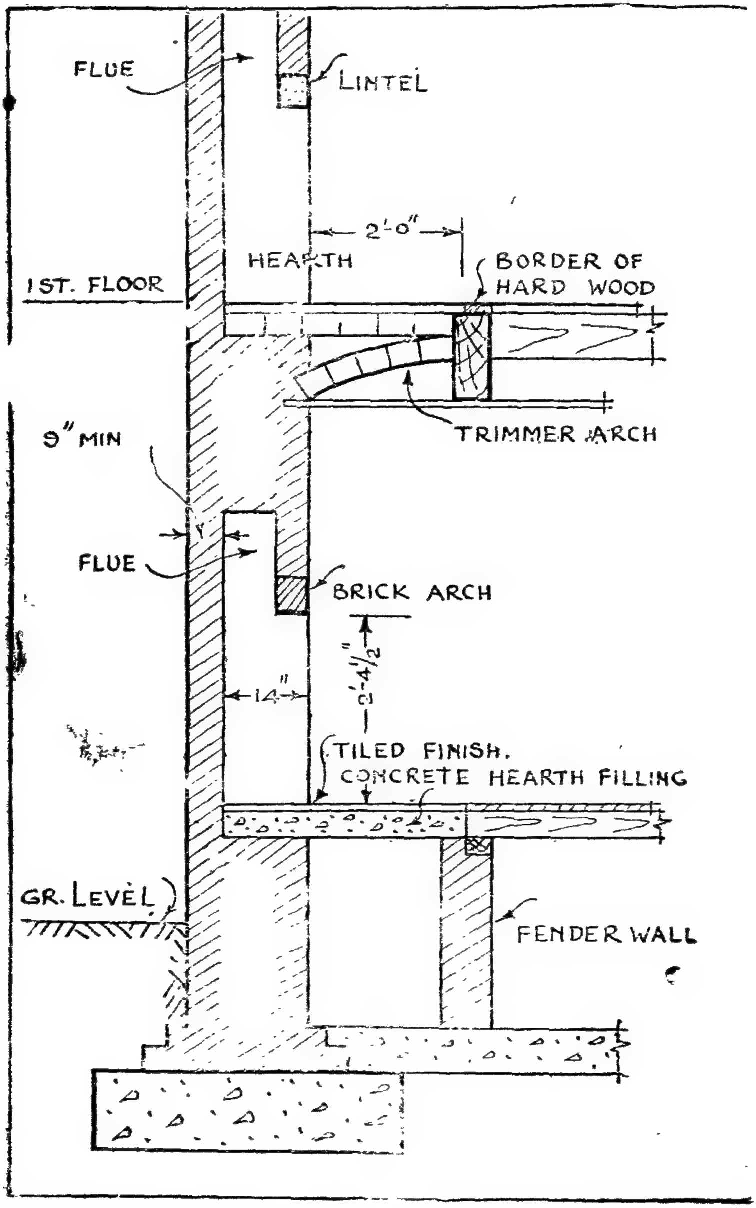


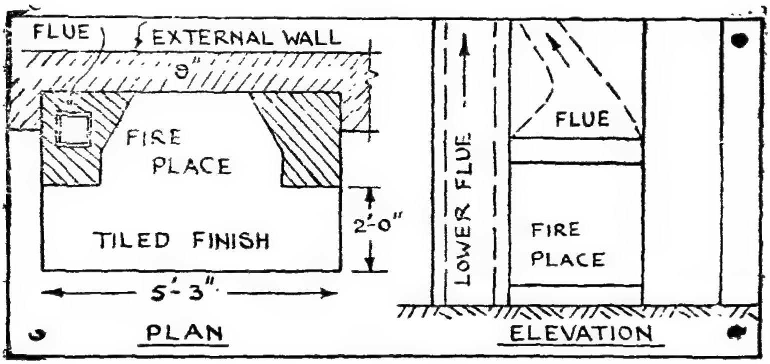
Fig. 160. Details of fireplace construction.

inserted at the junction of the outer and the inner sections. Similarly a damp proof course is provided just below the commencement of the hollow wall.

Art. 71. Fireplace Openings—The provision of fire places and the connecting chimney flues is also an important aspect in house construction. Fire places are usually a source of trouble, if not properly constructed. The precautions to be taken while designing them are:—

(i) No wood framing of floors and roofs, and no other wood work should be placed within 12 ins. of any flue.

(ii) When a common chimney is designed to serve several fireplaces on different floors, a separate flue should be provided for each fire place.



Figs. 158 and 159. Showing the arrangements of flues.

(iv) No flue should be inclined at an angle less than 45°, and the bends in each flue should be properly rounded off. No abrupt offsets should be given as these will cause large accumulations of suit, in addition to their obstructing the draught. See Figs. 158 and 159.

(v) Flues may be round or rectangular. Round flues are conveniently formed with vitrified stoneware pipes. The normal size of a rectangular flue serving a single fireplace is 9" × 9". The size is increased upto 14" × 14" depending upon the number of fireplaces connected to it. The inside of the flue

should be preferably lined with fire-clay. Alternatively it may be pargeted, i. e. rendered with mortar which is a mixture of cement, sand and a fire proof material.

(vi) A fireplace usually requires greater depth at right angles to the wall. It may therefore project into a room or project outwards in the external face of the wall. Fireplaces are also placed cornerwise in a room. The opening for a fireplace is provided with an arch or an R.C.C. lintel. The formation of jambs, hearth and the supporting trimmer arch are shown in Fig. 160.

The chimney stack is carried sufficiently high above the roof and is fitted with a suitable capping. Smoke outlets are provided in the side walls of the stack.

Art. 72. How to Construct Masonry—In order to construct brickwork in proper alignment, a corner of the wall is first built upto a height of one foot to form a lead. A setting out rod or gauge rod should be properly marked out to indicate the number of course per unit height. At the other end of the wall or at intermediate points,—if the wall is very long,—separate leads are also raised. Each course is then laid between these leads with the aid of a mason's string or line string.

Mortar is first spread uniformly on the lower course already laid, and each brick or stone is placed and finally set in position, by pressing it and gently moving it horizontally, until mortar squeezes out at the joints. The extra mortar is then cut off from the joints by a trowel. During this operation it should be noted that the line string when once tied up, is never touched until the whole course is laid in alignment with it. The use of a distance piece is recommended for the purpose. During the construction of masonry all the precautions as detailed in Arts. 56 and 63 should be observed.

It is necessary to see that the leads mentioned above are built perfectly in plumb. A plumb bob is used for the

purpose. When the height of a wall exceeds 4 to 5 ft. above the ground level, the bricklayers require raised platforms for the whole length of the wall to proceed with the work vertically. The platforms are provided by a system of temporary timber structure known as scaffolding, the details of which are given in a different chapter later.

Art. 73. Thickness of Masonry Walls—The strength and stability of a brick masonry wall depends upon the thickness to which it it built up, assuming that other factors such as the type of bricks, mortar and bonding, are the same. The nature and intensity of stresses set up at any section due to different kinds of loads acting on it, also have an effect upon the stability of a wall. As brick masonry is made up of independent units, any stress that tends to destroy the cohesion between these units is detrimental to it. Hence brick masonry should not be stressed to bending or tensile stresses. It should be stressed only in direct compression and shear, which should not exceed the safe limit permissible for that class of masonry.

The loads acting on a wall are, (i) partly due to its own weight (dead load), and (ii) partly due to the other members of a structure resting on it (dead and live loads). In addition there is (iii) the wind load acting on exposed walls. These loads and their effects are studied by considering the stability of one foot length of that wall and the required thickness is then specified.

Various regulations are laid down for the minimum thicknesses of walls in relation to their height. Stone walls are generally thicker by 3 ins. to 4 ins. than brick or concrete block walls. The usual thickness for the later is about one-sixtith of its height.

But for these walls when they extend over several stories, the thickess for the top 25 feet is kept as 12 to 13½ ins. and could then be increased by 4 to 4½ ins. for the next lower 25 ft. and so on.

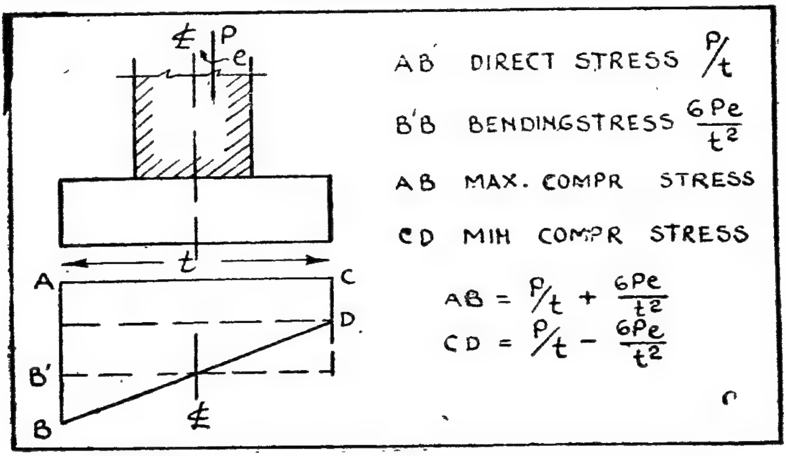
Stresses in Brick Masonry—(i) *Axial Load* acting at the centre of a section causes direct stresses so that if P is the total axial load in tons acting centrally at any section in masonry, the axial pressure p' is given by,

$$p' = \frac{P}{A} \text{ tons/sq. ft.; } A = 1 \times t \text{ sq. ft.}$$

where A is the area of the wall section in sq. ft. and t is the thickness of wall in ft.

(ii) If the same axial load P acts eccentrically at the section, then bending stress p'' is given by,

$$p'' = \frac{6Pe}{t^2} \text{ tons/sq. ft. where } e \text{ is the eccentricity in ft.}$$



Figs. 161 and 162, Stress distribution on foundation due to eccentric loading.

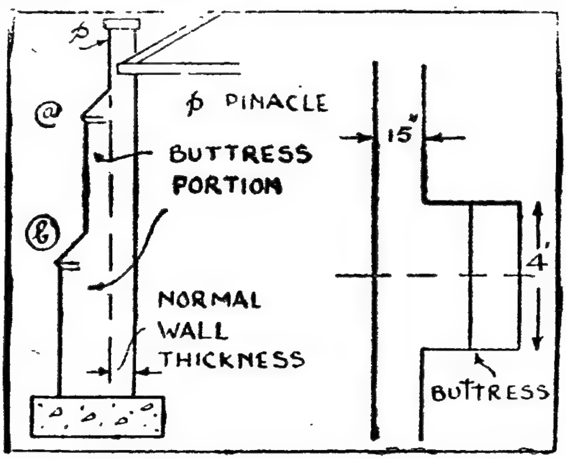
(iii) As the bending stresses are acting in opposite directions on either side of the wall, the maximum and the minimum stresses at the extreme edges of the wall or at the two wall faces, are given by,

$$p = \frac{P}{A} + \frac{6Pe}{t^2} \quad \text{or} \quad p = \frac{P}{A} - \frac{6Pe}{t^2};$$

$$= \frac{P}{t}\left(1 + \frac{6e}{t}\right) \quad \text{or} \quad p = \frac{P}{t}\left(1 - \frac{6e}{t}\right);$$

Taking the negative value, since no tensile stresses are permitted in masonry, as previously pointed out, the permissible eccentricity is limited to t/6 *i. e.* the thickness o a wall should be six times the eccentricity.

The positive sign in the above value of extreme stresses gives the maximum direct stress at the outer faces of the wall. This should not exceed the safe stress limit, permissible for the type of masonry specified for the wall. The weight of brick masonry is generally taken as 125 lbs.



Figs. 163 and 164. Showing details of Buttresses

/cu. ft. In Figs. 161 and 162 are shown the two types of stresses given above.

For a circular section of masonry, the permissible eccentricity for an axial load is $\frac{1}{8}d$ where d is the diameter of the column.

Art. 74. Wind Pressure and its Effect on Walls—Wind pressure acts on walls in a direction transverse to their axis, and consequently produces bending and sliding effect on them. Of these two, the bending effect only need be considered.

The tensile and compressive stresses at the extreme faces of a wall, due to bending, are given by,—

$$\frac{\text{Bending Moment in ft. tons.}}{t^2/6} \text{ tons. / sq, ft.}$$

where t is the thickness of wall in feet.

The pressure due to wind is usually taken as 15 to 20 lbs./sq. ft. on the projected area of the exposed face. For buildings in costal towns, a higher value should be used.

The combined effect of the various types of forces. enumerated above should be considered while designing a wall and testing it for stability.

Buttresses–Walls also carry eccentrically placed heavy loads or oblique thrust due to arches, at intervals of their lengths. In such cases, intead of designing the wall of a greater thickness uniformly for the whole length, buttresses are provided so that their vertical weight together with the eccentric load or the oblique thrust forms a resultant force to cut the base of the buttress within the middle third. If necessary a pinacle is built on top of the buttress to add to its weight. See Figs. 164 and 165.

Sometimes, the widening of the buttress at intervals *a* and *b* as shown in Fig. 164, is necessary to bring the resultant thrust within middle–third and thus stabilise the buttress against over–turning.

CHAPTER VII

Composite Masonry and Partition Walls

Composite work of stone and brick masonry--ashlar facing and rubble or brick backing- Stone facting slabs with brick or concrete backing. Use of concrete in walling--Cast in situ and pre-cast concrete walls. Pre-cast concrete block masonry.

Brick and tetra-cotta partition walls. Brick negging. Glass partitions. Lath and plaster partitions. Use of furring in partitions-reconstructed wood boards and metal lath.

Art 76. Composite Work of Stone and Brick Masonry–The common type of masonry in this varity adopts stone work on the face and brick work for the backing. Stone facing may be either of natural or of artificial stone and the bonding between the face work and the backing can be secured either by means of headers projecting into the backing or by means of metal cramps, joggles, dowels and lead plugs. It should be noted that on account of a greater number of joints in the backing, the mortar used in that masonry work should be somewhat stronger than that used for the face work. It may be claimed that this prevents the unequal settlement and the consequent separation between the facing and the backing.

(i) *Ashlar Facing and Rubble or Brick Backing*—The selection of stone work for facing is mainly due to its appearance and massive imposing character in addition to its durability. In Fig. 165 is shown composite masonry walling of rubble backed ashlar work. The method of providing brick backing to ashlar facing is indicated in Fig. 166. In addition to the quoins being placed alternately as shown in the above two figures, through bond stones from face to back of the wall are also provided. For ordinary work, rubble facing is also backed with brick masonry.

(ii) In another form of composite masonry, finely

dressed stones are used as quoins in corners around openings and in architrave, and specially selected well burnt bricks

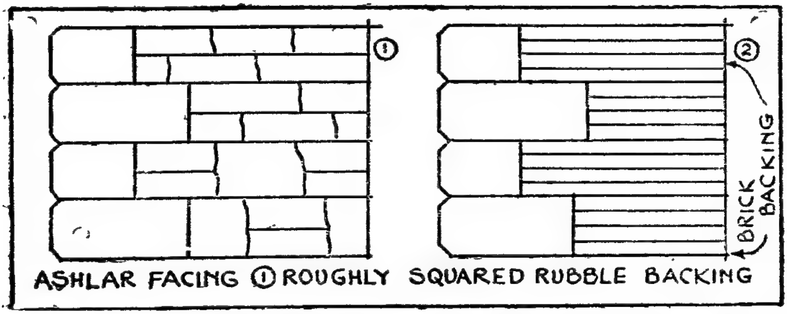
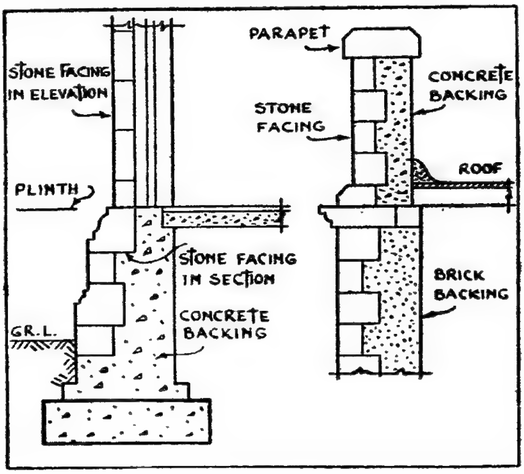


Fig. 165. Composite masonry. Ashlar facing rubble backing.

Fig 166 Composite masonry. Ashlar facing with brick backing

of uniform colour are used for facing. In such case, backing may be of rubble or of ordinary bricks. Figs. 167 and 168

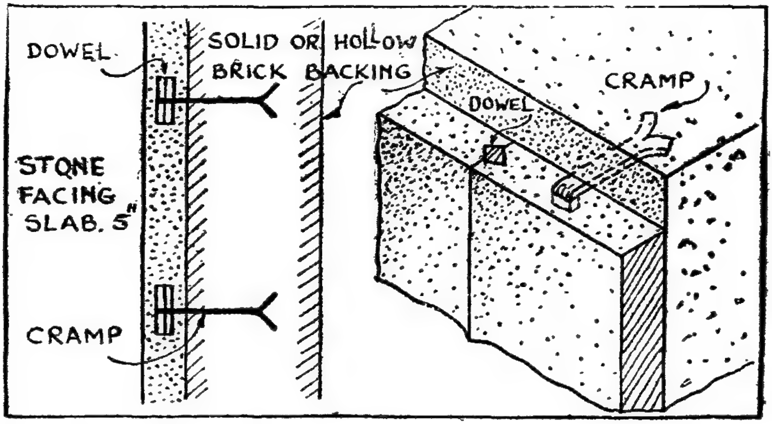


Figs. 167 and 168. Stone facing to brick concrete backing in plinth and parapet.

indicate methods of using stone facing to brick or concrete backing in plinth and parapet respectively.

Art. 76 (a) Stone Facing Slabs with Brick or Concrete Backing–*Veneered Walls*–In modern practice, large stone slabs 4" to 6" thick are used as facing to brick or concrete

backing instead of small independent units as already stated. The stones may be natural stones obtained from a good granite or sand stone quarry, or artificial ones specially moulded for the purpose. Similarly the bricks used for the backing may be solid or hollow, and the concrete also may be plain cement concrete or reinforced cement concrete.



Figs 169 and 170. Details of composite masonry with stone facing slabs fixed to solid or hollow brick backing or concrete backing.

See Fig, 169 and 170. Stone facing can be provided to steel framed buildings also or to buildings framed in reinforced concrete. Over this wide range of materials good many varieties of composite masonry could be built. Metal cramps are used at all horizontal and verticle joints to fix the stone facing slabs to brick backing, whereas dowels are used at these joints to bind the stone slabs with each other.

(b) **Brick Facing**—Similarly brick facing could be used with rubble backing for external walls. Special type of glazed tiles of clay are manufatured as facing tiles to effect the desired decorative appearance. In lavatory blocks glazed tile facing is very common for sanitary purpose. Terra cotta products and marble slabs are also used as facings for walls.

Art. 77—Use of Concrete in Walling—Concrete is used in the construction of walls,—(i) either as plain or

reinforced concrete cast in-situ, (ii) or in the form of panels or blocks,—either solid or hollow, which may be cast in -situ or pre-cast. The usual ratio of cement, fine aggregate and coarse aggregate is 1 : 2 : 4 respectively. It may be said that in general concrete construction is strong, rigid and permanent and ultimately results in the saving of both labour and materials. It has water-proof qualities as a homogeneous and a monolithic body, when properly cast.

R. C. C. Walls (i) *Cast in-Situ*—For thin walls upto 4″ the reinforcement is placed centrally and consists of either B. R. C. fabric or steel rods tied horizontally and vertically. But for thicker walls, reinforcement is used on both the sides, and rods are placed both ways. Proper shuttering or form work should be provided for placing the reinforcement and pouring the concrete. A R. C. C. wall of this type is shown in Fig. 171. The steel rod reinforcement is placed centrally in the wall thickness, and the wall is cast monolithic with the R. C. C. column. The use of plain concrete in walls is already explained in the previous article. For basement walls and foundation walls, cement concrete, properly reinforced, is generally recommended. They withstand earth pressure and exhibit water-proof qualities. For vaults and strong rooms R. C. C. walls are invariably used.

(ii) *Precast R. C. C. Walls*—These are built of precast horizontal slabs which are inserted in the grooves of precast concrete posts. See Fig. 172. The joints are then filled with neat cement mortar. Such walls are well suited for cheap and quick construction of small buildings, garages and fence walls.

Art. 78. Precast Concrete Block Masonry-The use of pre-cast concrete blocks and tiles as independent units for the construction of walls, is now a very common practice in many construction works. This is mainly due to the possibility of attaining a greater speed in the construction

of walls. The walls are also thinner and possess greater resistance to extreme changes in the atmosphere, specially when the blocks are hollow.

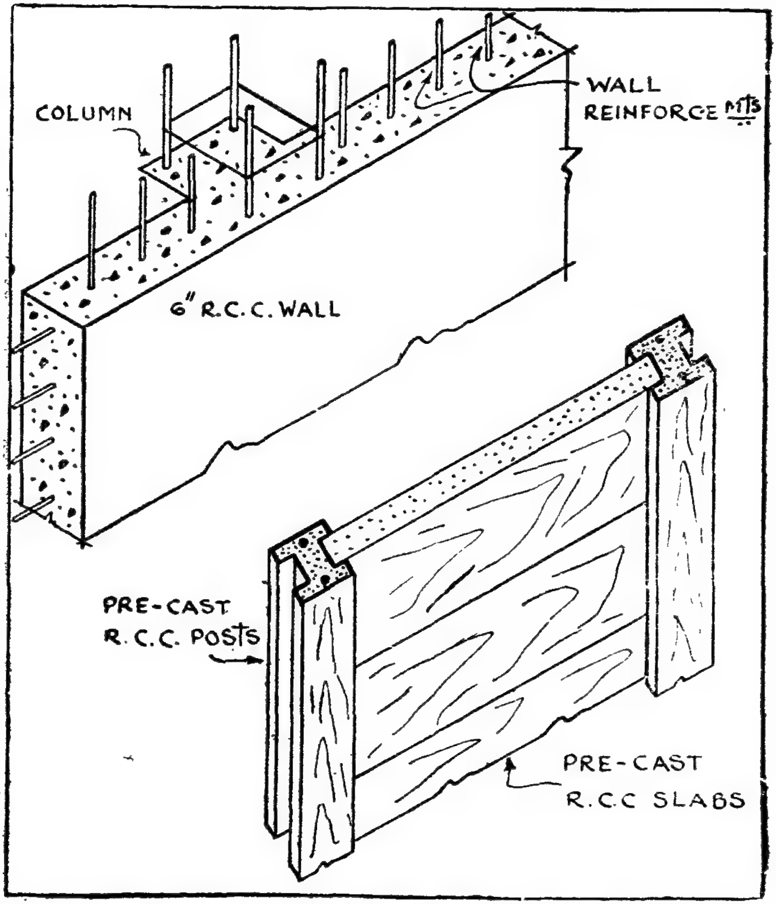


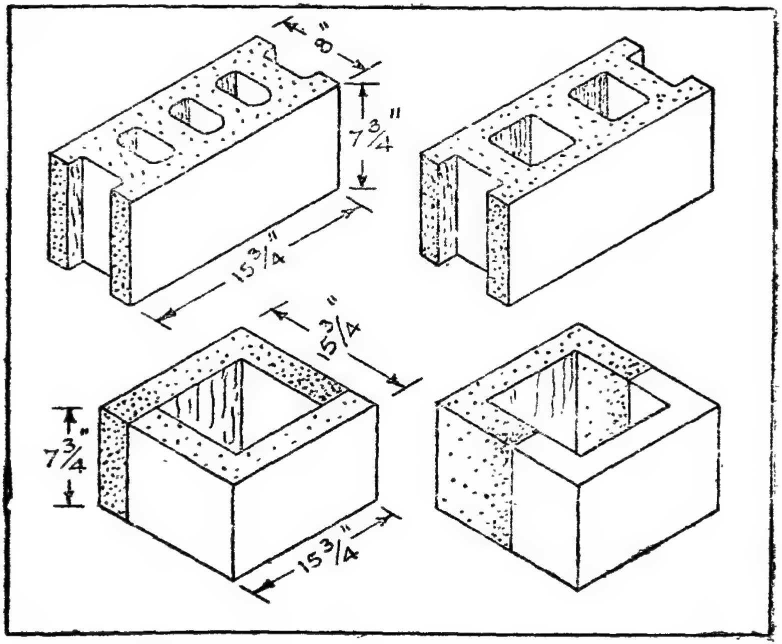
Fig. 171. Cast in-situ R. C. C. wall with steel for rod reinforcement.
Fig. 172 Precast R. C. C. slab wall.

Concrete blocks are made in various sizes; but the *standard size of blocks* is 16 ins. × 8 ibs. × 8 ins. This gives a wall 8 ins. thick with each course 8 ins. *Hollow Partition blocks* are thinner in section, varying from 4 ins. to 6 ins. But their height and lenght are the same as

those of the standard size. *Concrete Building Tiles* have a size of 12 ins. × 8 ins. × 5 ins. It may be noted that the lengh and height of the above blocks and tiles include a side and a bed joint of $\frac{1}{4}$ in. each.

The common types of concrete blocks and tiles given above are shown in Figs. 173 and 174. Some concrete blocks are also made in two pieces, the varieties of which are shown in Figs. 175 and 176.

The amount of air space is approximately $\frac{1}{3}$ rd the volume of hollow blocks. But sometimes this air space is



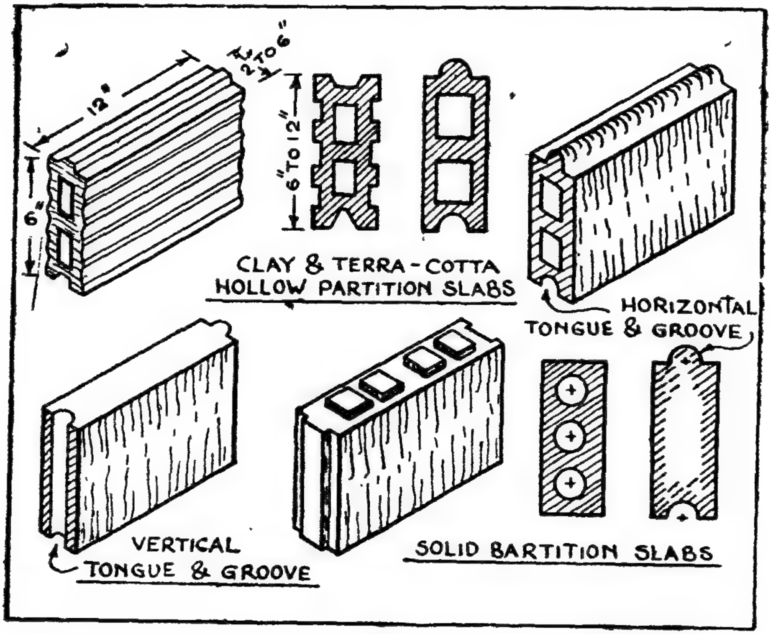
Figs. 173. and 174, pre-cast concrete blocks Single units.
Figs. 175 and 176. per-cost concrete blocks. Doubble units.

increased to 40 per cent when light and more economical units are aimed at. Special types of blooks and tiles to suit the requirements of corners, sills, lintels, jambs for openings in walls, are also moulded.

The use of hollow concrete blocks for sound proof

and heat proof construction, is explained later.

Art. 79. Concrete Wall Finishings—Concrete wall facings can be finished in various ways. In a finishing termed as *Form Finish*, the surface is left as it is after the forms are removed. This requires form work to be

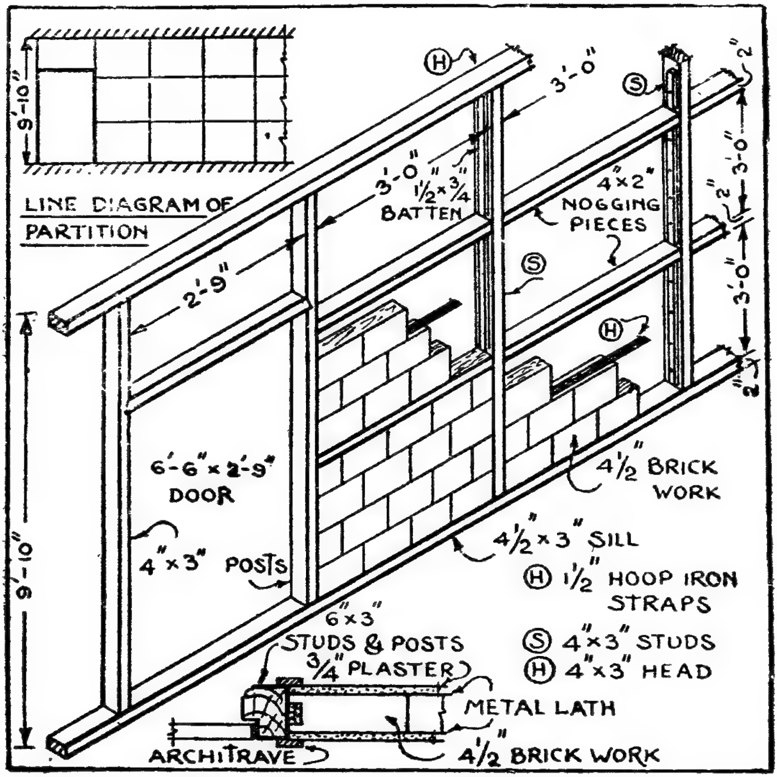


Figs. 177 to 184.
Different types of Hollow and solid clay and terra-cotta partition slabs.

exact and accurate. In *Plaster Finish*, an additional rendering coat of plaster of ½″ to ¾″ is applied after the forms are removed. While in a *Decorative Finish*, ornamental tiles, marbles or terra-cotta facings could be used as before. The type of finish generally depends upon the purpose to be served by the wall.

Art. 80. Brick and Terra-Cotta Partition Walls—Bricks and terra-cotta blocks, like pre-cast and cast in-situ concrete, are also used for constructing partition walls. Bricks may be used on edge or on flat and to give strength to brick masonry, every third or fourth course is reinforced

with hoof iron, B.R.C. fabric, expanded metal roll or wire netting. The thickness of the partition wall including that of plaster on both the sides is $4\frac{1}{2}$ ins. when the bricks are laid



Figs, 185 and 186. Details of brick-nogged partition wall.
Fig. 187. Line diagram of the above.

on their edges, and 6 ins. when they are laid on their flat side. In Figs. 177 to 184 are shown typical clay and terra cotta hollow and soild blocks commonly used for constructing partition walls. It is desirable that cement mortar should be used for building thin partition walls for strength.

Art. 81. Brick-nogging—Sometimes timber frame work consisting of horizontal and vertical members, known as nogging pices and studs, is built to form panels of app-

roximately 3 feet square. the top and bottom horizontal mem bers are called head and sill. The panels are subsequently filled with brick masonry, which is plastered on both the sides, if required. This method of construction is known as *Brick nogging* and is shown in Figs. 185 and 186. The line diagram of a complete partition is shown in Fig. 187.

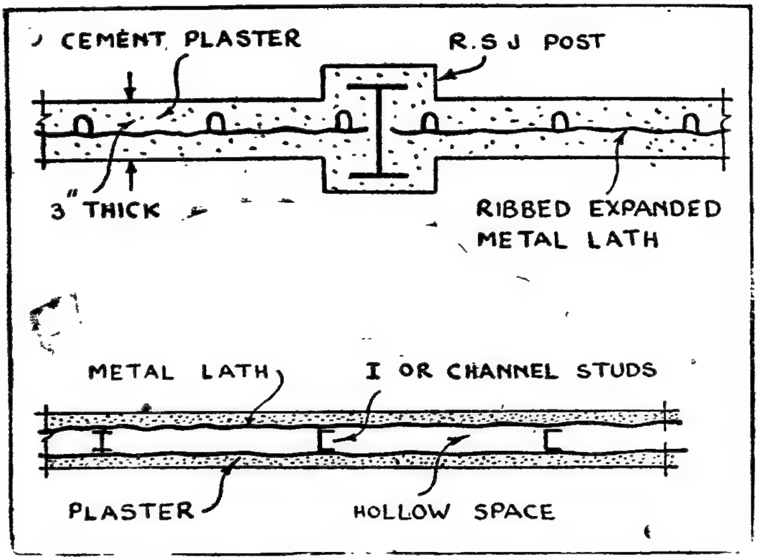
To secure connection between the two studs and the bricks, $1\frac{1}{2}'' \times \frac{3}{4}''$ battens are placed as shown in the figure. Similarly the brick work is reinforced in the manner mentioned in the previous article at every alternate or third course. The ends of the reinforcement are bent up about an inch and nailed at the sides of the vertical members or studs. Brick–nogged partitions could be provided with plaster and metal lath should be used in such cases as shown in the above figures.

Art. 82. Glass Partitions—Transparent and opaque varieties of glass, set in wooden or metal frames, have been in use for many years as materials for light partitions. But these ordinary varieties of glass have one objection that they are breakable. But in modern practice this defect is overcome by improved methods of manufacture so that the structural glass of the present day is properly tempered to increase its strength and resistance to shock. Sheet glass is reinforced with woven or welded wire netting for the same purpose. It does not produce splinters if it breaks. Bullet-proof glass consists of very thin sheets cemented together under heat and pressure. Another variety of shatter proof safty glass is the three-ply glass where three pieces of glass are cemented together with thin laminae of transparent celluloid.

Structural glass is available in sheets of thickness varying from 3/8 to $1\frac{1}{4}$ in. and in different colour. Some varieties have a highly polished surface and decorative features. Structural glass is widely used for partitions and as lining for concrete and brick walls, in lavatories, kitchens and dining halls where good sanitary conditions have to

be maintained. Glass blocks are not suitable as load bearing members.

The use of glass blocks to which structural properties are imparted, for the construction of partitions, is also very recent. Glass blocks may be solid or hollow. Solid blocks carry side and top joggles to facilitate construction. Thin block and



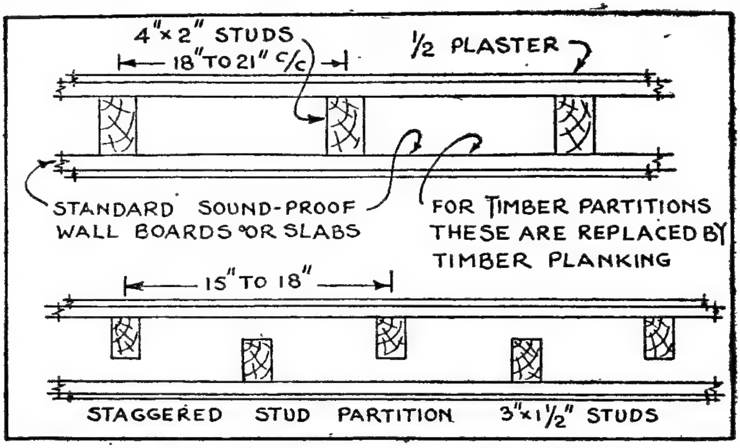
Figs. 188 and 183, Lath and Plaster partitions.

slabs are provided with grooves on all sides through which slender reinforcing bars are passed and embedded in cement mortar to impart strength.

Art. 83. Lath and Plaster Partitions—For permanent and superior work only metal lath should be used. It is available in different patterns, such as, woven wire lath, expanded metal lath, ribbed metal lath and corrogated expanded metal lath.

Metal lath, by virtue of its open spaces and corrogations in its surface, forms a rigid backing or foundation for plaster. Cement plaster is struck on both the sides of the lath and the resulting partition is very thin and strong. See Figs. 188 and 189. Lath and plaster partitions possess fire resisting quatities.

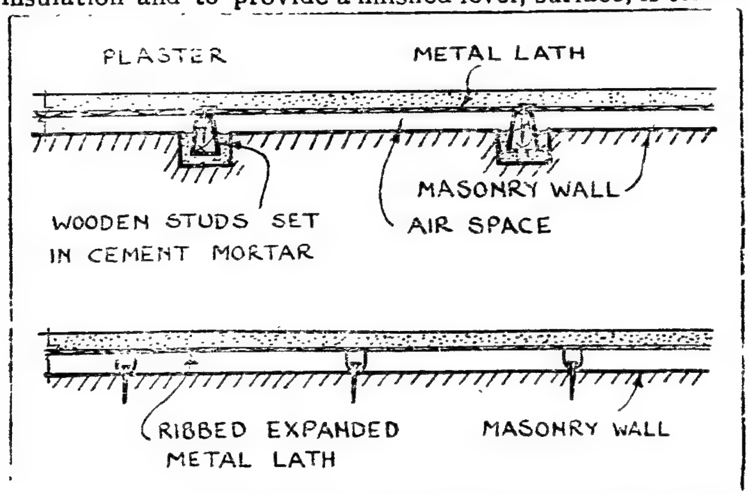
Teak wood framed partitions are also used, as explained later under sound insulation, covered on both sides



Figs. 190 to 192. Standard wall board partitions.

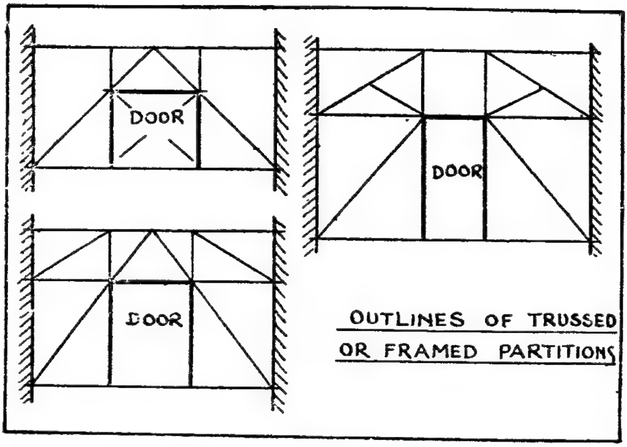
by teak wood plantes or hard wood boards. See figures on page 118 for outlines of such framed partitions.

Art. 84. Use of Furring in Partitions—The use of frame work of wood or metal to provide an air space for insulation and to provide a finished level, surface, is termed



Figs. 193 and 194. Showing methods of providing metal lath and plaster to existing masonry partitions.

as furring. In its simplest form, furring consists in providing a frame work of timber, on both the sides of which are fixed patent wall boards of reconstructed wood of various designs, such as ply-wood, masonite and asbestos wood, etc.



Outlines of trussed or framed partitions.

The wall boards are availble in standard sizes and the frame work also carries panels to suit them, to which they are fixed by screws. Specially prepared strips may be used to lap over the joints to improve the appearance. An air space is locked up between the two sides and acts like good sound and heat insulator. See Figs. 190, 191 and 192.

Instead of wall boards, metal lath is employed with a continuous rendering of cement plaster, and the frame work of timber may be replaced by vertical studs of I-sections or channels. See Fig. 189.

Existing masonry partitions may also be provided with metal lath and plastering with an air space formed in between them. Differnt ways of providing furring to walls are shown in Figs. 193 and 194.

Masonry Columns and Pillars could also be provided with facings with any of the following:—tiles, marble slabs, lath work and plaster, wood boards of proprietory products, plywood, etc.

CHAPTER VIII

Arches and Lintels

Arches and lintels--their functions and structural aspects. Arch and its stability. Terms used. Classification of arches, Methods of constructing brick arches--rough arch; axed or rough--cut arch and guaged arch. Bond in brick arch. Stone arches, Concrete arches, Arch centerings. Thickness of arch rings.

Lintels of wood and stone. Lintels of rolled steel sections-plain and encased. Lintels of reinforced concrete. Reinforced brick lintels.

Art. 85. Arches, Lintels and their Functions— *Purpose*—Openings are required in walls for various purposes, such as for the location of doors, windows, cupboards and for passages between rooms. An opening in a wall is a weak point and affects its strength in general. It therefore requires to be very carefully and soundly built. The vertical sides of openings are called jambs and the method of constructing them with the aid of quoins is explained under "masonry", In this chapter, the various methods of bridging the tops of opening with the aid of *arches* and *lintels* are explained. The construction of sills or the bottoms of these openings also has to be carried out according to standard methods and is detailed under the chapter on "doors" and "windows". Thus it will be seen that all the four sides of an opening require proper attention during the construction of walls, and particularly those in external walls, which should be weather proof in addition, and the exclusion of sun and rain are often primary factors.

The chief functions to be performed by an arch or a lintel are :-

(i) To support the load of the wall above them.

(ii) To impart the necessary strengh and unity in wall binding together the jambs at their top.

(iii) To give facilities for fixing the door and window frames, wherever they are used.

(iv) Asthetically ,to add to the appearance of structure.

(v) To provide structural facilities for fixing chajjas and weather shades.

Arches and lintels serve the same purpose, but structurally function in a different manner. An *arch* offers a horizontal thrust and tends to push the wall outwards. This lateral thrust is more, if the arch has proportionately a smaller rise. For arches that are built in a wall with their plane coinciding with the face of the wall, proper supports should be constructed to take up this thrust and transfer it to the main body of the wall. For arches abutting against a wall, tie rods are provided for binding their two ends and thus to make an arch partly self-supporting. But it is claimed that arches give a better scope for providing and creating several varieties of architectural effects in monumental structures. *Lintels*, on the other hand, do not exert any oblique thrust on the supporting wall, but rest on the sides of openings like a beam and transfer the load vertically.

Art 86. Arch and Its Stability—An arch is (i) a mechanical arrangment of wedge-shaped blocks laid in mortar, (ii) mutually supporting each other, and (iii) placed over an opening in the form of some curve, (iv) to carry the wall and load above. The stability of an arch depends on the requirement that the blocks with which an arch is built up should press mutually; and that there is no-tension at any section in the arch. This is only possible if the thickness of the arch and its curve are so designed that the line of resistance at any section falls within the middle-third of the arch. The safe resistance of the material of an arch should not also be exceded; and the bed joints should be arranged normal to the curve of the arch.

Art. 87. Terms Used—The following are the terms in used in connection with arches and lintels. See Fig. 195.

(i) *Voussoirs* are bricks or stones or precast blocks, forming the courses of an arch. They are usually wedge

shaped. *Springer* is the voussoir placed next to the skew back, and *Keystone* is the uppermost or central voussoir of an arch.

(ii) *Extrados*, back or top of an arch is the upper or convex side of an arch. *Intrados*, soffit or bottom of an arch is the underside or concave side of an arch. *Crown* is the highest point in the extrados.

(iii) *Skew-Back* is the inclined surface in the abutment or pier, specially worked in a radial direction to form a bearing surface for the end of an arch. The springer or the first voussoir rests on this surface.

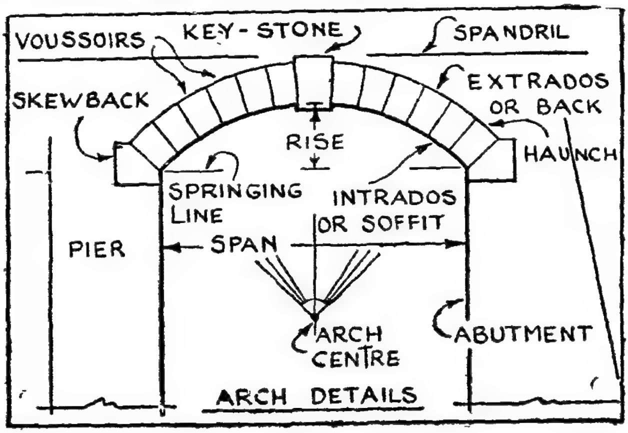


Fig. 195. Showing different terms used in arch.

(iv) *Springing Points* are the points from which the curve of an arch springs or commences.

(v) *Abutment* is the end support of an arch designed to resist the inclined thrust of an arch or a series of arches. They are wider and have more weight than ordinary piers. If lintels, beams and girders are used instead of arches, their end supports are also termed as abutments.

(vi) *Piers* are intermediate supports of a series of arches or an archade. This term is also used in connection with lintels, beams and girders.

(vii) *Span* of an opening is the horizontal distance between the supports of an arch, lintel or beam. "*Effective*

Span'' as distinguished from ''*Clear Span*'', is the horizontal distance between the centres of bearings, and is invariably used for all design purposes to calculate the strength of a member. *Rise* of an arch is the vertical distance from the springing point to the highest point in the intrados.

(viii) *Haunch* is the lower part of an arch between the skew back and half way up to the crown.

(ix) *Spandril* is the irregular trangular filling to the right and left of an arch, on the extrados and upto the horrizontal line drawn tangent to the extrados at the summit.

Art. 88. Classification of Arches—The classification of arches is usually made:—

(i) By the number of centres from which the arch curve is struck.

(ii) By the type of ·workmanship employed in constructing an arch.

Sometimes arches are also classified by their historical or architectural features.

(i) Classifying the arch by the number of centres from which the arch curve is struck, we have the following varieties,—

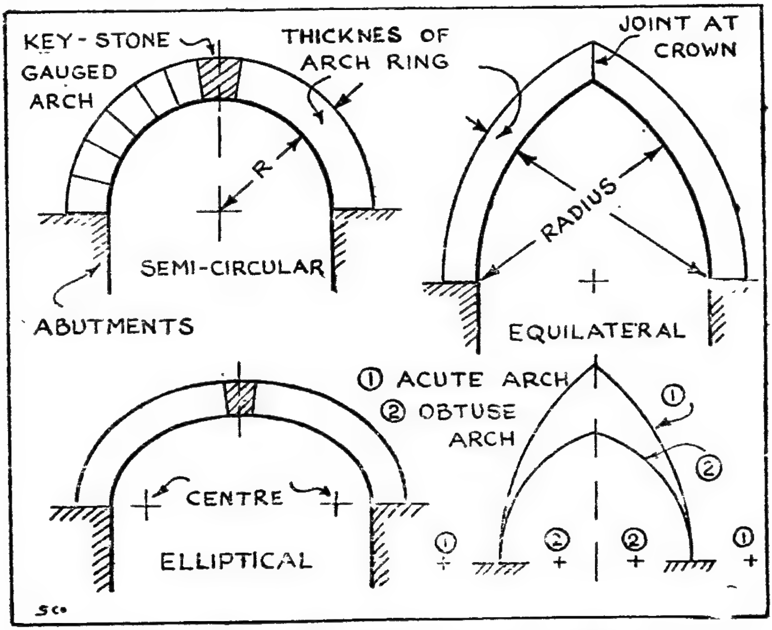
(a) *One Centred Arch,* such as semi-circular, flat, segmental, Moorish or horse shoe, and wheel or Bull's eye.

A semi-circular arch see Fig. 196, has its centre at the springing level whereas the segmental and horse-shoe arches. are struck with their centres below and above the springing point respectively. A Bull's eye is an arch, the ring of which is a complete circle, see Fig. 203. A flat arch, also known as the *Camber arch,* is set out as shown in Fig. 201. All the bed joints are laid radial from the corresponding centre. Flat arches are given a camber of $\frac{1}{8}$ inch per foot of span The construction of a fiat arch and the formation of skew back and jambs are shown in Fig. 200.

(*b*) *Two-Centred Arches* are those whose curves are

struck from two centres, such as equilateral, Fig. 197; acute and obtuse arches, Fig. 198.

(*c*) *Three Centred Arch* or approximately Ellipse, True Elliptical arch, See Fig. 199, parabolic arch, pointed arch are the other varieties of arches.



Figs. 196. to 199. Different types of arches.

(*d*) *The Ovoid Sewer* section shown in Fig. 202 is struck from four centres, each centre being separate for crown, invert and the two sides. Fig. 284 is an illustration of an inverted arch, commonly employed for foundation designs, to distribute the pressure on the foundation bed.

It is so called on account of its inverted position, since the crown is below the springing and the centre is above the springing.

(e) *Relieving arches* are built over some lintels and flat arches for the purpose of carrying the weight of the wall above them, and thereby relieve them of the load which

they would have otherwise borne. Such a relieving arch is shown in elevation and section in Figs- 205 and 206. The wood lintel shown in the above figures is in two pieces and bears only the load of the filling between itself and the relieving arch. A relieving arch is also termed as a "*Discharging Arch*".

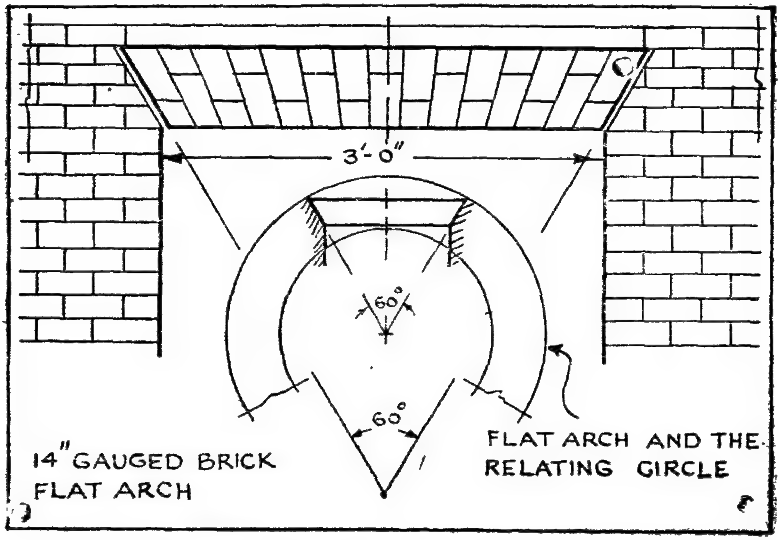


Fig. 200. Flat arch shown in elevation.
Fig. 201. Development of a flat arch.

Art. 89. Methods of Constructing Brick Arches Classification—(ii) According to the second classification of arches, as stated in the previous article, depending on the workmanship and the bricks used, we have,—

(*a*) Rough Arch ;

(*b*) Axed or Rough-cut Arch ;

(*c*) Gauged Arch.

A brief description of these is given below :—

(*a*) *Rough Arch* is constructed of standard bricks with paralle lsides. The bricks are not wedge shaped but have their sides tangential to a small circle around the arch center, the

diameter of which is equal to the thickness of the brick. See Fig. 207. This results in the formation of wedge-shaped or V-shaped bed joints.

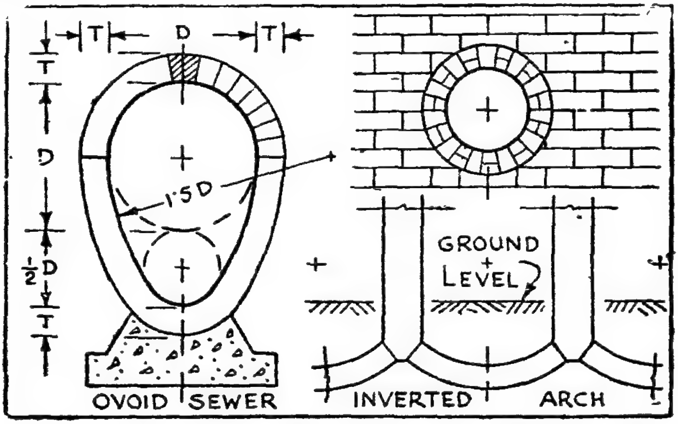
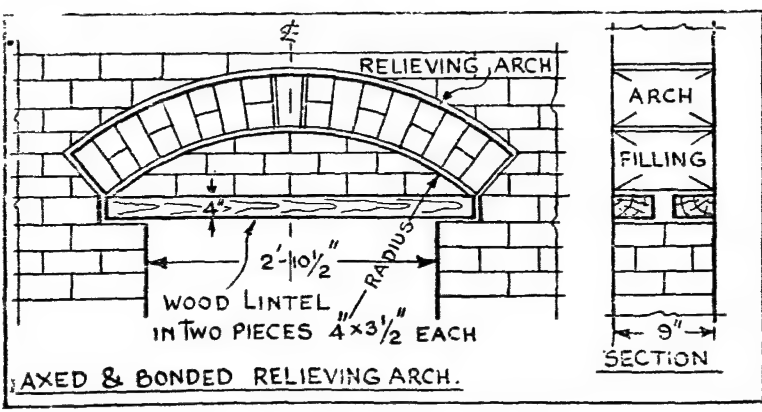


Fig. 202. Ovoid sewer section, Fig. 203. Ball's eye. Fig. 204. Inverted arch.

A rough arch, if built with whole brick on edge as shown in Fig. 208, will have bigger sized V-joints. This necessitates



Figs. 205 and 206. Relixing arch.

a rough arch to be built of half-brick rings, each of 4½ ins. thickness. See Fig. 209. This has the effect of V-joints less

pronounced. The springer is used as a whole brick to spread the load on a built up skew back.

(b) *Axed or Rough-Cut* Arch—In this type of arch voussoirs are formed of bricks that are roughly cut to a wedge shape by means of a brick-layer's axe. The sides

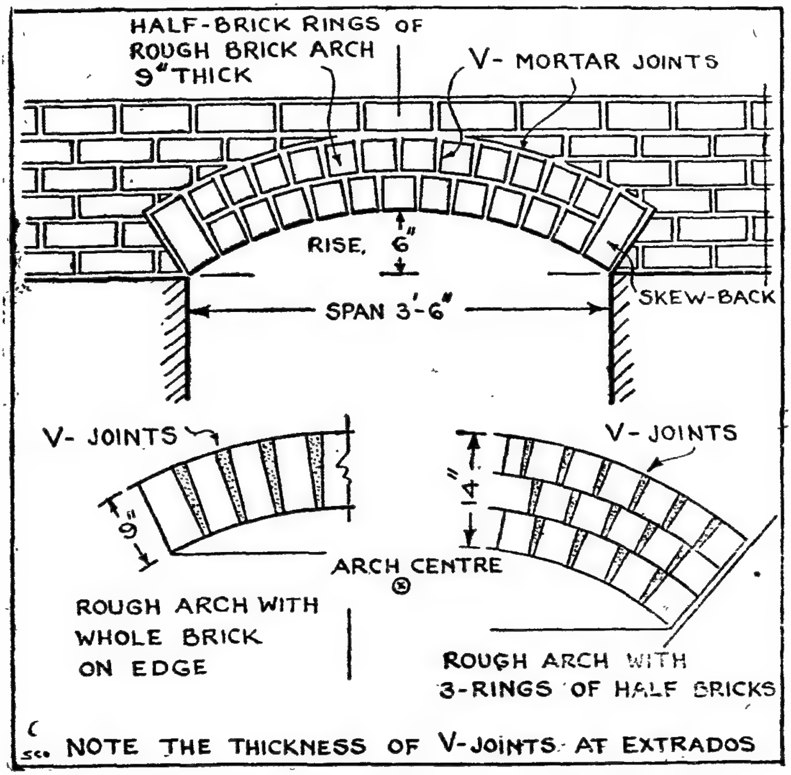


Fig. 207. 9" thick roubh brick arch with half brick rings
Fig 206. Rough brick arch with whole brick on edge.
Fig. 209 Rough brick arch with 3-ring with half bricks.

radiate from a common centre, as shown in fig. 205. Thus forming the bed joints of regular thickness throughout.

(c) *Gauged Arches*—The principle of constuction of a gauged arch is the same as that of an axed arch, but the workmanship is of a superior quality. The bricks are accurately cut and neatly dressed to a wedge shape. Thus joints

in a gauaged arch are fine, thin and truely radial. For high class wark the bricks are also rubbed to show a very smooth surface. Often bricks are specially moulded to the required wedge-shape, for this class of work, to suit the radius and the span of the arch. In such a case, the arch is termed as *moulded brick arch.*

Art. 90. Bond in Birck Arches—Arches are built (i) either in the form of concentric rings whole half-bricks; or (ii) by the arrangement of voussoirs as headers and stretchers.

(i) In the first method, the concentric rings are usully of half-brick thickness, and all bricks are laid as headers.See Figs. 199 and 201. The radial joints in each ring are non-con trinuous. Sometimes in arches of bigger spans, bond blocks are introduced between two concentric rings to prevent them from being separated from each other and thus from causing a failure.

(ii) In the second method of constructing an arch by placing the voussoirs as stretchers and headers, proper tansverse bonding in the interior of the arch is secured. This is necessary in a wide or a deep arch. Unlike the type of concentric rings, the bed joints in this method are kept continuous and radial. See Fig. 205.

Art. 91. Stone Arches—Like brick arches, stone arches may be circular, segmental, elliptical, pointed, or flat. They are built with voussoirs which are dressed to a wedge shape of the required size, for each arch. Hence it is possible to keep all bed joints radial. The full sized arch is first set out on a level piece of ground and sizes of each voussoir and the key-stone are worked out by slight adjustment. Templates are then prepared for being supplied to stone dressers for dressing them.

Ashlar and cut stone arches are the principle varieties of stone arches where better stones and good workmanship could

be employed. They are adopted for superior work where great strength and appearance are essential. For ordinary work rubble arches are also constructed.

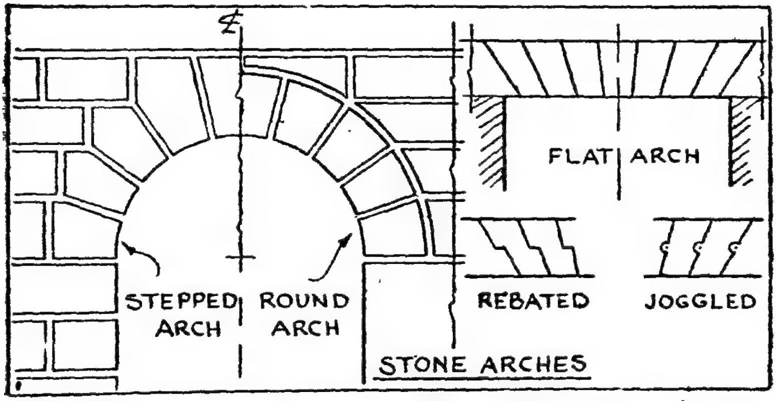


Fig. 210. Stone arches. Stepped arch and round arch.

Fig. 211. Flat arches of stone.
Fig. 212 and 213. Methods of securing stone voussoirs.

In fig. 210 are shown the two types of stone arches, viz., the stepped arch and the round arch, It will be noticed that the former is more stable than the latter in as much, each voussoir in it carries a shoulder which secures a proper bond into the courses of the wall. This also prevent the slinding tendency of the top wall load on the back of the arch.

A flat arch is shown in Fig. 211. The methods of securing the voussoirs by means of rebates ane joggles are shown in Fig. 212 and 213.

Art. 92. Concrete Arches—The use of concrete in arch work to span the openings in walls of building is mainly in the form of precast blocks without reinforcement. The cast in-situ concrete work for monolithic arched floorings is given later. Similarly cast in-situ concrete arches are employed for arched culverts and bridges.

Voussoirs, keystones and skew backs are specially moulded for the type of the arch for which they are to be used. They are therefore gauged arches. Well graded and correctly proportioned cement concrete is used for the purpose. Complete

curing of the blocks is necessary before using them. Once the precast blocks of concrete are manufactured, other details of construction are similar to those of stone and brick arches.

Art. 93. Methods of Constructing Arches—Arch Centering—All arches prior to their construction across a span, require the provision and erection of some form of a temporary structure to support them. This temporary support is known as *Centering.*

The requirements of an arch centering are,—(i) It must be sufficiently strong to support the arch and rigid enough as not to be destorted under loads of materials and workmen moving over it during the construction of the arch. (ii) It must be capable of being removed after the arch is set without causing any ditsurbance to it.

Ordinarily in buildings, the centerings for arches are constructed of wood, though steel centerings are employed when a number of similar arches have to be struck. In its simplest form, a centring consists of a pair of solid ribs cut from planks of the required thickness and width. The tops of the ribs are worked to the intrados curve of the arch. On top of these ribs are fixed laggings which consist of battens driven across from face to back of the arch and joining the two ribs. See Fig. 214.

At the two ends of the ribs, bearing piece are fixed to rest the centering on supports. Between the bearing pieces and the supports, wedges are provided to facilitate the easing of the centering. Proper care should be taken to see that the supports, rest on a hard base. In Fig. 215 is shown the section of the same centering at the centre.

The types of centerings suitable for bigger spans as met with in buildings are shown in the following Figs.216 to 219.

Instead of using one solid rib, built-up ribs are employed, and to impart rigidity, braces, and ties are provided.

Temporary supports for small arches are made in a very simple way. A thick horizontal plank is supported on four to six props at the springing level and bricks are aranged

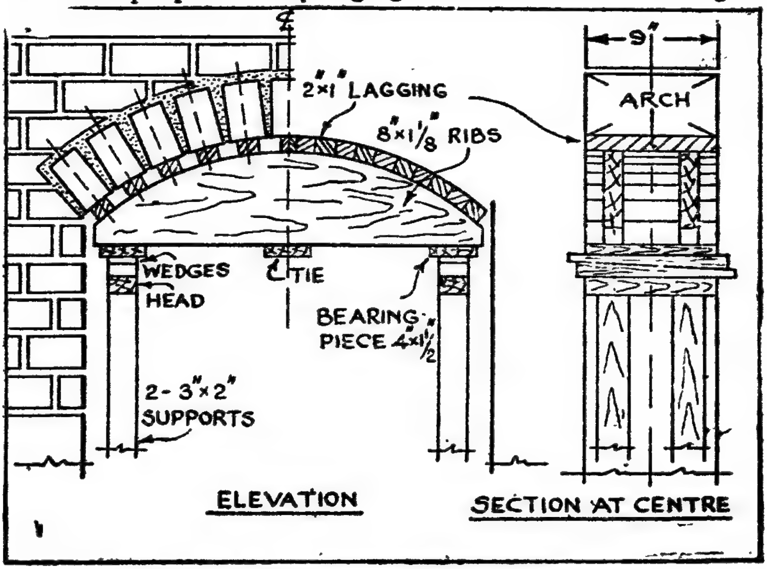


Fig. 214. Arch centering for small spans.
Ftg. 215. Arch centering in section.

on this plank roughly to the shape of the intrados. On top of this brick,-work, a plaster of mud is applied to give a uniform surface for the intrados of the arch to be constructed.

When the centering is erected then masonry work or concreting as specified for the construction of the arch, is taken up.

Art. 94. Thickness of Arch–The thickness of important arches is usually determined by drawing their stability diagrams for the span, rise and the loading in each case Butf or small arches as are commonly met with in buildings, the following rules may be used to determine their thickness, T.

(i) Single segmental arch,

$$T = \sqrt{0.12 \times \text{Radius}}, \quad \text{feet.}$$

(ii) Single semi-circular arch,

$$T = \sqrt{0.20 \times \text{Radius}}, \quad \text{feet.}$$

(iii) Series of segmental arches,

$$T = \sqrt{0,17 \times \text{Radius}}, \quad \text{feet.}$$

(v) Series of semi-circular arches,

$$T = \sqrt{0.25 \times \text{Radius}}, \quad \text{feet.}$$

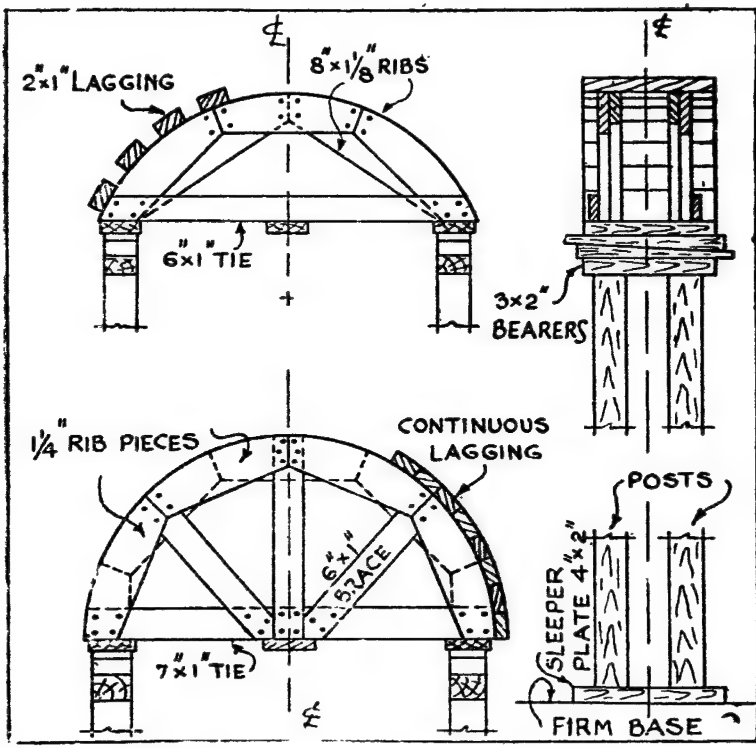


Fig. 216 to 219. Ribbed arch centerings suitable for bigger spans.

Art. 95. Lintels—Early in this chapter, the various functions of lintels have been ennumerated. The details about their construction and the materials used will now be considered.

Lintels are constructed of various materials such as wood, stone, rolled steel sections either alone or in combi-

nation with other materlals, reinforced concrete, reinforced brick work. A typical lintel resting across a clear span of 3′–3″ is shown in Fig. 220.

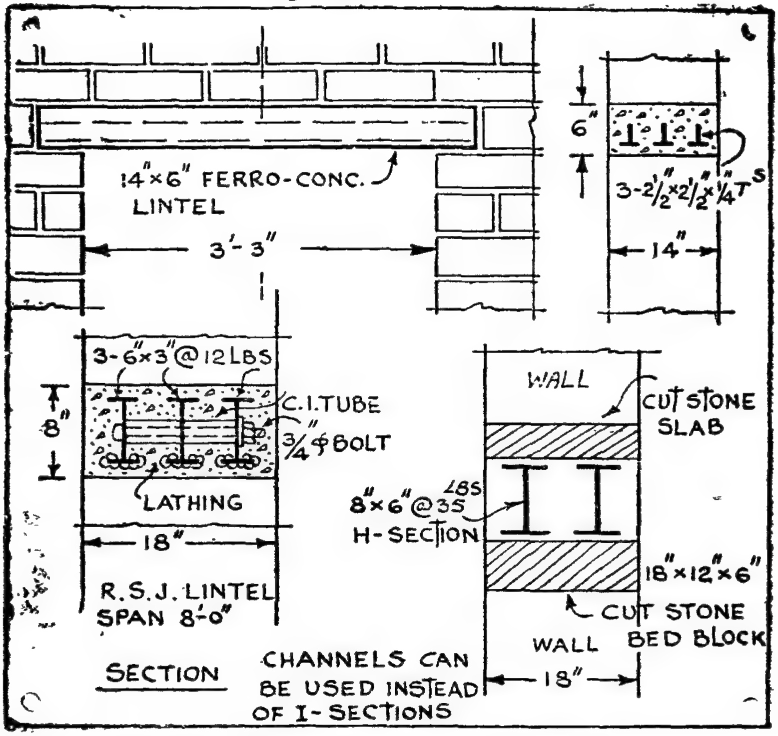
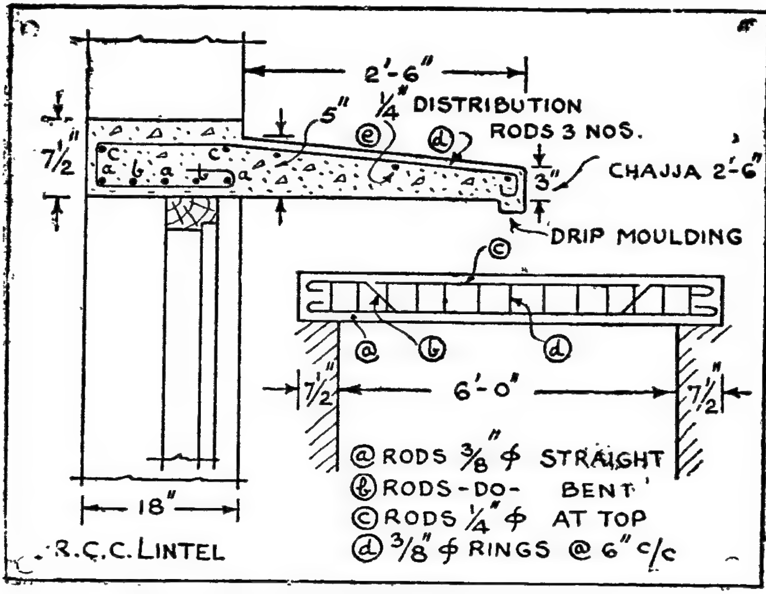


Fig. 229. A typical lintel Span 3′--3″ clear.
Figs. 221 to 222. Lintel. R, S. sections and concrete.
Fig. 223, Lintels, R, S, joists and cut stones.

Wood and Stone Lintels—The use of wooden sections and stone slabs for bridging across an opening and to bear the top load of the wall, is practised from very early times. But wooden lintels are costly and are laible to be destroyed by fire and decay. Single sections of wood or built-up sections of two or more pieces held together by bolts, are employed for the purpose. Similarly stone lintels, except in locality where suitable stone is available, are very rarely used on account of their high cost of transport.

Art. 96. Lintels of Rolled Steel Sections—These are suitable for wide spans and heavy loads. The use of R. S. Joists with cut stone slabs is shown in Fig. 223. Proper bedblocks or templates, either of stone or of cement concrete, should be provided at the supports for the ends of lintels to rest upon. L-iron and T-sections are suitable for lintels in a similar manner.



Figs 224 and 225, Reinforced concrete lintels

Lintels are also formed of rolled sections embedded in cement concrete as shown in Figs. 221 and 222. The following points deserve attention for such types of construction :-

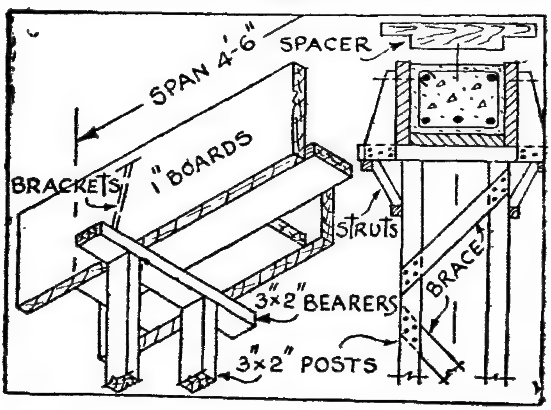
(i) Cast iron or steel distance tubes should be introduced between the adjacent rolled steel sections, and bolts should be passed through to hold them in position.

(ii) At the underside of the sections, metal lathing should be provided to give a proper grip to concrete for adhering to the steel section.

Art 97. Lintels of Reinforced concrete—Plain cement concrete and brick masonry have very little flexural strength.

Their use to span an opening in the form of an arch, where only direct compressive stresses have to be resisted, has been already considered. But if these have to be employed for lintels where flexural strength is needed, some form of steel reinforcement is necessary to resist the bending stresses.

In Figs. 224 and 225 are illustrated R. C. C. lintels commonly used in buildings. They are either pre-cast or cast in-situ. The one shown in Fig. 224 carries a chajja or a canopy in front of it. Owing to the possibility of casting concrete to any shape, and to its low cost of maintenance, R. C. C. lintels are invariably used in modern practice. From the construction point of view, proper care should be taken to see that the reinforcement is correctly placed in position. and that the cencrete is homogeneous and thorougly cured.

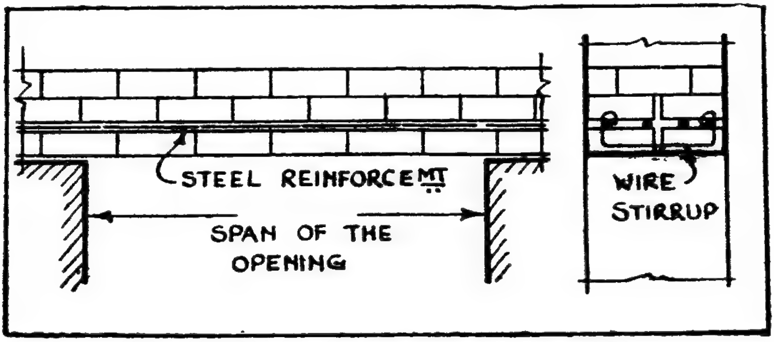


Figs. 226 and 227. Form work for R. C. C. lintels.

As in the case of arches, concrete lintels also require a form work for their laying and construction. In Figs. 226 and 227 are given the details of form work commonly used fcr the purpose of casting R. C. C. lintels.

Atr. 98. Reinforced Brick Lintels—Liniels are also constructed of bricks reinforced with steel bars or flats. The reinforcement is introduced between the courses of bricks in a manner similar to that in reinforced concrete. The brickwork which is built with bricks placed either on edge

or fiat, takes compression and steel reinforcement takes tension. A gentle camber is given to the lintel and the transverse joints are arranged to radiate from a common centre to improve the appearance. The longitudinal joints are arranged continuous and the reinforcement is placed in



Figs. 226 and 229. Reinforced brick lintel.

these joints. Cement mortar is used for the constructon of this type of lintels. To impart lateral strength, wire stirrups are also provided transversely to tie up the reinforment and to hold in position the bricks in the lower course. See Fig. 228 and 229 for details of construction of such lintels.

CHAPTER IX

Joints and Joinery

Wood work--wrought and put up. Temporary and permanent carpentry. Non-load bearing and load-bearing timber members. Terms used in carpentry and joinery.

Principal joints used in carpentry. Lengthening joints; Widening joints; Transverse joints--bearing joints. framing joints. Mortise and tenon joints and its varieties. Oblique joints. Fastening.

Art. 99. Wood Work—"Wrough and Put up"— Structural timber as obtained from depots is rough and unwrough. It requires to be cut, planed and framed for employment in building work. This art is known as "*Carpentry*" and "*Joinery*" and has to be carried out according to recognised methods to impart requisite structural qualities to the finished work. Timber which is thus finally placed in position in building is termed as "*Wrought and Put Up.*"

Art. 100. Temporary and Permanent Carpentry work—The use of timber for construction falls into two principal catagories :—

(i) *Temporarily during construction* as in the case of scaffolding, shoring and strutting, timbering of excavations, false work, and centering to arches, etc. This timber as the name implies, does not remain in position after the structure is finally constructed. Its use is only during construction.

(ii) *Permanently in a Building* as a part of it, as in the case of trusses, columns, girders, beams, joists, boarding of wood floors doors and windows, etc. Timber trusses and roofing, partitions and doors ete. In this chapter are given the details and the methods of using timber permanently in a building.

Art. 101. Permanent Carpentry—Structurally for permanent work timber is used for two distinct purposes,—

(i) *Non-Load Bearing*,—for doors, windows, partitions and decorative work.

(ii) *Load Bearing Membes* : for timber members used in floors and roofs, posts and staircases. etc.

Joints play an important part in the work of a carpenter, though the final finishing of the exposed faces of wood work has to be duly attended to whenever required. The essential requirements of joints are tightness and delicasy. They should not as far as possible be prominetly visible to the eye. The differnt types of joints in carpentry are given in the following articles.

Art. 102. Terms used in Joinery—The following are the terms commonly used in describing joinery work.

(i) *Chamfering* indicates the process of cutting away the edges or arrisis of a timber piece. The exposed edges of wood are usually rounded off or chamfered. This also adds to the appearance of the jointed work. The inner edges of horizontal rails and stiles of a door panel are usually chamfered, and a V-joint is formed at their junctions. If the chamfer is not continued to their junction point, but ends either in another chamfer or in a slope, it is called as stopped chamfer.

(ii) *Plough Grooving* is the operation of cutting grooves parallel to the grains for decorative work. When a groove is cut accross the grains it is called *Trenching*.

(iii) *Rebating* consists in cutting away a rectangular portion from the edge of a timber piece of sufficint depth for another piece similarly cut to fit in. Sometimes one timber piece is only cut to receive the whole of piece. (*a*) The jointing of floor boards, and (*b*) the formation of a rebate in the door frame to receive a shutter, are the examples of the two types of rebating.

(iv) *Mitring* indicates the method of intersecting two pieces of timber meeting at an angle. The intersection is

termed as metre. Special mitre blocks are provided to cut the edges of pieces at the required angle. Different types of mitred joints are described later.

(v) *Veneering* consists in providing a thin sheet of timber, usually of a superior quality, to cover the exposed face of another timber which is of an inferior variety. The aim is to mainly improve the appearance of wood work. The inner work is intended to satisfy the structural needs whereas the veneered facing is intended for ornamental or decorative purpose.

(vi) *Mortising* is the cutting of a rectangular recess in one member to receive a projection, or tenon at the end of another member. If the mortise does not pass through the entire thickness of the member, it is termred as *Stub-mortise.*

(vii) *Tenoning* consists in forming a projection or tongue at the end of a piece. Usually the section of the piece is reduced to form a tenon. The tenon fits into the mortise cut in the other timber piece to form a joint commonly known as *Mortise and Tenon* joint. Mortise and Tenon joints may be, shouldered, dovetailed, tusk, haunched, stub, housed, chase, forked, etc,

(viii) *Dovetailing* is the method adopted to join two boards usually at right angles to each other. In the end of one board are formed fan shaped pins to fit in the similarly shaped sockets or mortises cut in the other. There are different types of dovetailed joints which are described later.

Art. 103. Principal Joints Used in Carpentry— Joints are classified according to the purpose which they are intended to serve in each case,—

(1) *Lengthening Joints.* These are employed for lengthening ties, struts, and members subjected to bending. These joints are necessary as very often the lengths of available timber sections are not sufficient and have to be extended to suit the required purpose.

(2) *Widening Joints*—are used to increase the width by jointing the planks of available smaller widths, as in the case of floor boarding or timber ceiling to roofs.

(3) *Transverse Joints.* These may be classified iuto two main types.—(i) *Bearing Joints* when one member rests transversely on another member and it is intended to transfer some load to the latter. In the formation of bearing joints due consideration should be the strength of the joints thus formed; and

(4) (ii) *Framing Joints*—used for framing doors, windows and partitions, where strength is not the main factor as rigidity and appearance.

(5) *Oblique Joints,* designed for framing heavy timber section at an angle which may be either acute or obtuse as in the case of trusses, heavy partitions, etc.

These joints will now be described in detail.

Art. 104. Lengthening Joints—These include lapping joint, fished joint, scarfed joint and built up joint. A single lap joint with U-stirrups of iron is shown in Fig. 230. Bolts should be used if the joint has to withstand tensile stresses in addition.

The two common varieties of fished joints are shown in Figs, 231 and 232. The two ends of the members to be jointed are butted against each other and iron or wooden plates, known as fish plates, are provided on each side of the joint. The respective members are then fastened by means of bolts.

In Fig. 233, is shown a scarfed joint suitable to resist compression. Another form of scarfed joint is shown in Fig. 234

Figs. 235 and 236 show a scarf with oblique surfaces with a pair of hard wood keys, used to tighten the joint. This is used to resist tension.

The joints shown in Figs. 237 and 238 are suitable for resisting both tension and compression. The surfaces are

jointed by indenting or tabling the parts together. In Fig. 238 hard wood keys are inserted with advadtage to strengthen the joint.

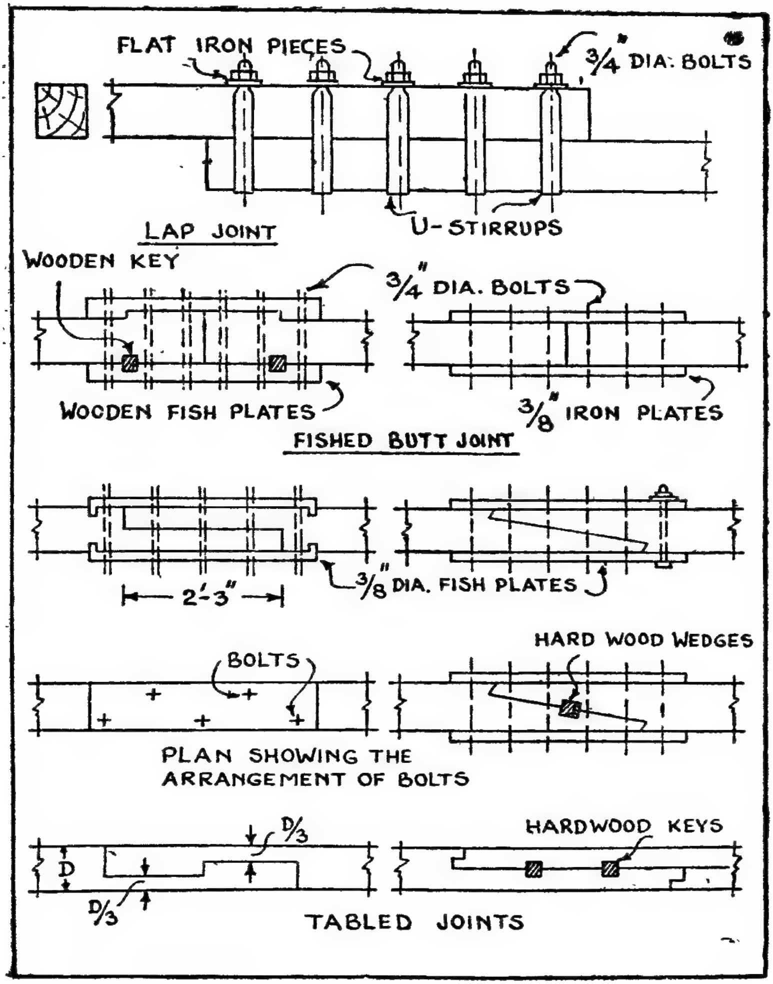


Fig. 230 Simple lap joint, U. strips.
Figs. 231 and 232. Common fished joints.
Figs. 233 to 236. Different types of scarfed joits.
Figs. 7 and 238. Scarfed joints to resist tension and compressien.

Timber members are also lengthend by building up smaller sections into several layers as in the case of curved built up ribs or laminated ribs. The joints are broaken and the respective pisition are held in position with the aid of bolts.

Art. 105. Widening Joints—Some types of widening joints are shown in the accompanying figures from 239 to 249. These joints are :– rebated joint, Figs. 239 and 240; tongued and grooved joint, Figs. 241 and 242; simple butt joint. Fig. 245; ploughed and tongued joint, Fig. 246 and 247; and rebated and filleted joint, Figs. 248 and 249. In addition to the above joints, we also have dowelled joint which is a butt joint to which additional strength is given by inserting round pins of hard wood or of metal in the meeting surfaces. The surfaces of the joints are preferably glued to prevent separation.

Art. 106. Transverse Joints—Bearing Joints—The following are the different types of bearing joints :—

(i) *Halving*–Two pieces crossing or meeting each other are jointed in a simple manner as shown in Figs. 250 and 251. Half the thickness of each piece is cut away to fit one end into the other. The upper and the under surfaces of the joint are made flush. In Figs. 252 and 253 are shown bevel and dovetail halving. These joints are used for wall plates and for fixing collar beams to the principals.

(ii) *Notching*—254 and 255 indicate the method of jointing by a single notch; and that shown in Fig. 256 indicates double notching when the notch requred is a deep one. Half the notch is cut in each piece. Notching is very commonly used for fixing joists to wall plates in a timber fioor. The shoulders formed in a notched joint prevent the joists from lateral movement.

A *Birds-month Joint*, in which notching is also used, is employed for fixing a common rafter to a wall plate or post plate. See. Fig. 476 under single roof.

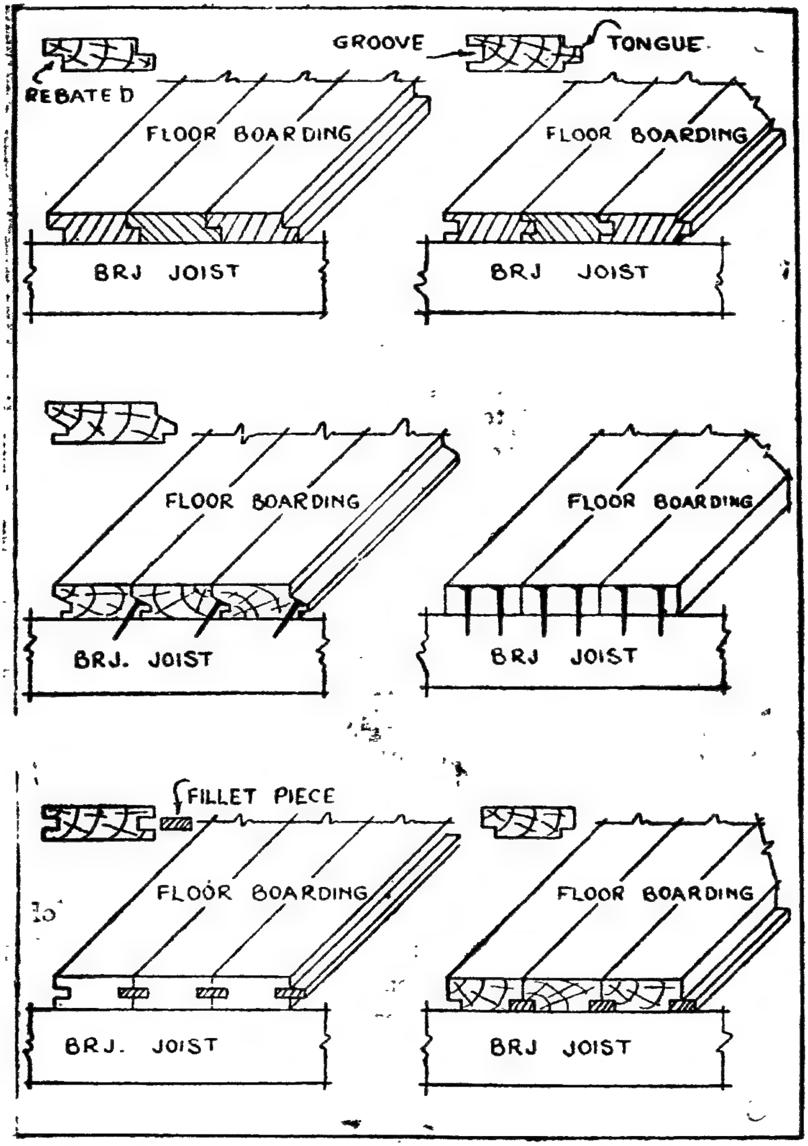


Fig.s 236 and 240. Rebated joint. Figs. 241 and 242. Tongued and grooved joints. Figs. 243 and 244. Rebated, tongued and grooved Fig, 245 simple butt joint. Figs. 246 and 247. Ploughed and tongued joint. Figs. 248 and 249. Rebated and filleted Joint.

(iii) *Cogging*—In Figs. 257 and 258 are illustrated the methods of making a joint where cogging is employed. Two notches are cut in the lower piece on either side of an uncut portion in the middle. The uncut portion is termed as cog. The upper piece contains a small notch which fits the cog of the lower piece. Joints are usually cogged on to the wall plate.

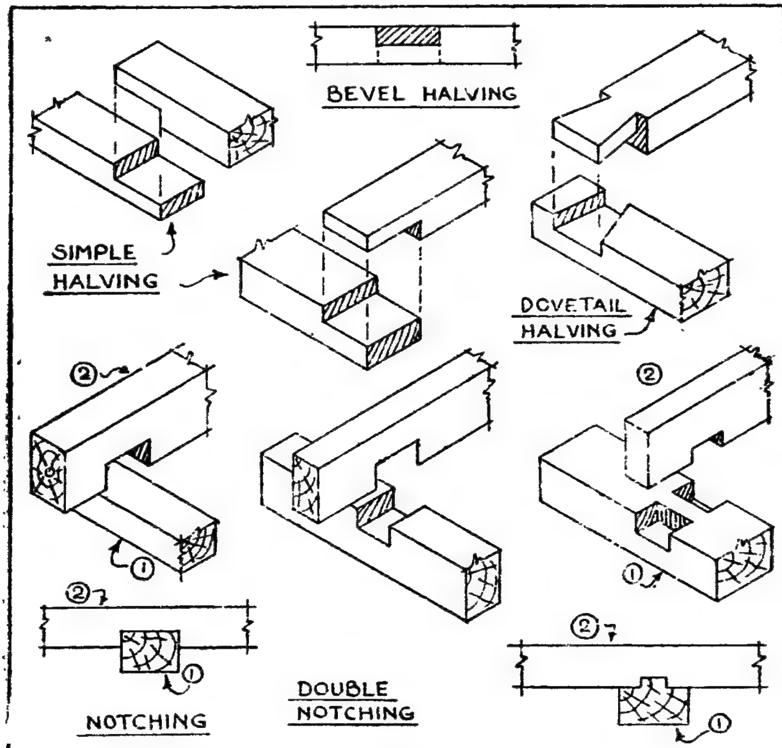
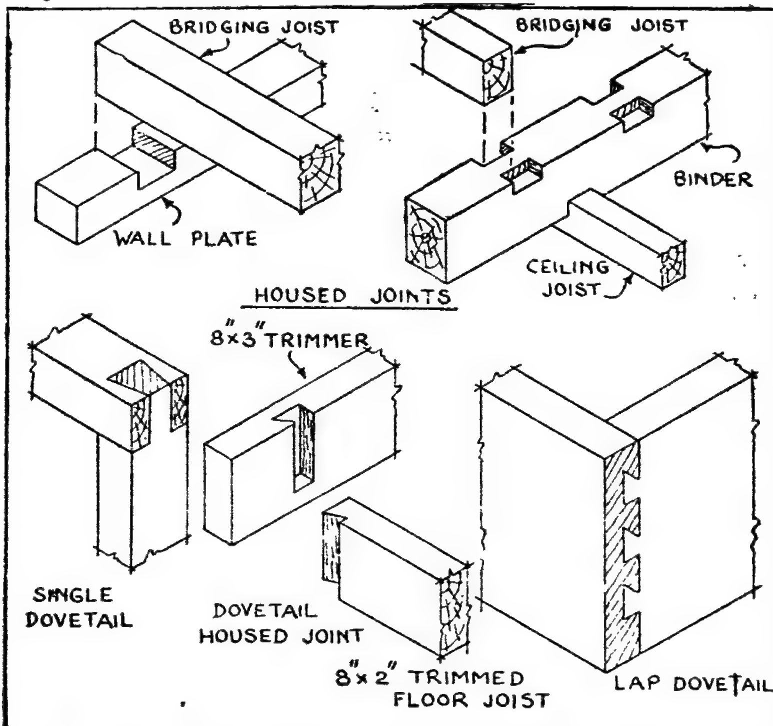


Fig. 250 and 251. Simple halving Fig. 252. Bevel halving.
Fig. 252. Dovetail halving. Figs. 254 and 255. Simple notching
Fig. 256. Double notching Figs. 257 and 258, Cogging.

(iv) *Housing*—When the entire end of one piece of timber fits for a short diistance into a notch cut into another piece, a housed joint is formed. In Figs, 256 and 260 are illustrated the methods of housing bridging joists into wall latpes and binders.

(v) *Dovetailing*—See (viii) in art. 101 also. Single dovetail joint when a vertical piece meets a horizontal piece is shown in Fig. 268. The method of fixing the ends of trimmed floor joists to trimmers is shown in Fig. 262. Lap dovetail joint is shown in Fig. 263.



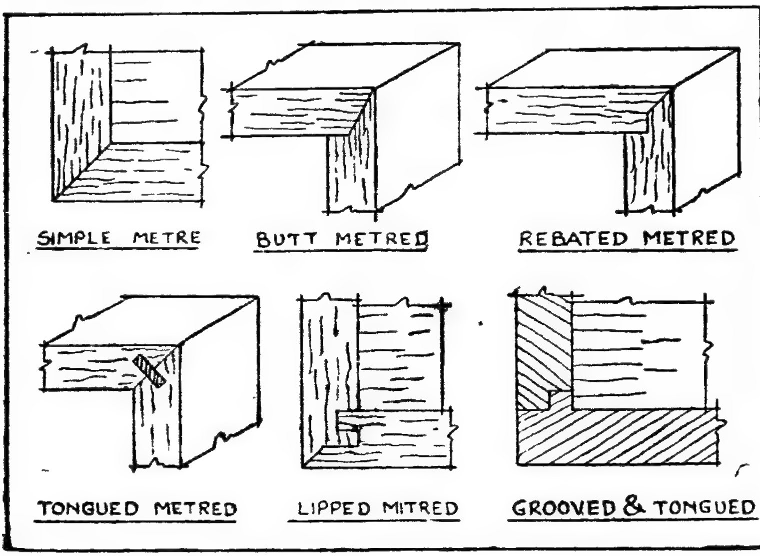
Figs. 259 and 260. Housing. Fig, 261, Single dovetail joint, Fig. 252. Use of dovetail joint in trimming; Fig. 263 Lap dovetaild jotnt

Art. 107. Framing Joints-(i) Angle Framing Joints- Mitred Joints. The different types of mitred joints are shown in Figs. 264 to 269. Simple mitre and butt mitred joints are shown in Figs, 264 to 265. Plain mitred joint has the disadvantage of showing light through the joint.

Rebated metred joint or ctherwise known as double butt joint, shown in Fig, 266 is used for superior work. Thougued

or keyed mitred joint, lipped mitred joint and grooved and tongued mitred joint are used where strenght and good work are essential. See Figs. 267 to 269. Glue is used in the making of such joints.

(ii) *Mortise and Tenon Joints*—The general description of mortising and tenoning is given under art. 102 (vi & vii). It



Figs 264 and 265 Simple mitred and butt mitred joints.
Fig. 266. Rebated mitred joint.
Figs. 267, 268 and 269.
Tongued, lipped, grooved and tongued mitred jonts respectively,

is a form of joint very commonly used for fixing two piece of wood at right angels to each other.

In an *Open Mortise* joint, the mortise is cut on the end of the piece and the tenon cut from the other piece fits in. A dovetail may also be formed in this case. See Fig. 251

Fig. 270 show a common form of mortise and tenon joint and a wedge piece may be used to tighten the joint. The width of the tenon is one-third the total width of the piece.

In the case of *housed tenon joint* shown in Fig. 271,

the entire end of one piece is fitted in the recess cut for the purpose in the piece and in addition a simple mortice

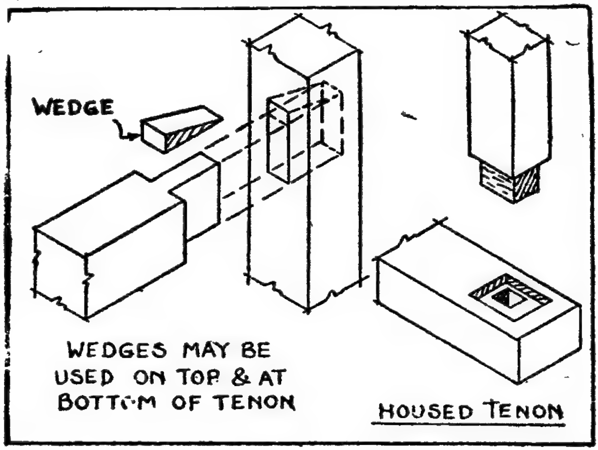
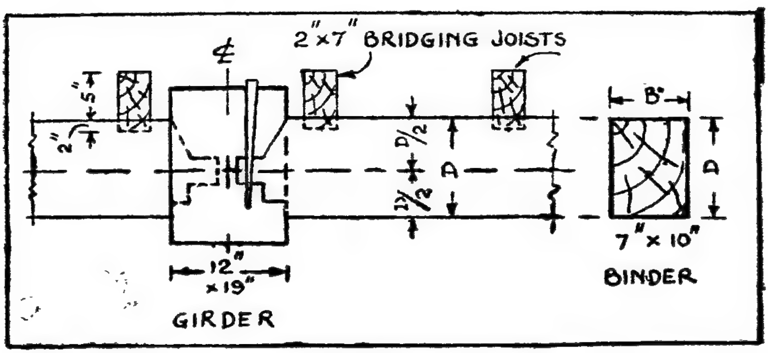


Fig. 270. Wedged mortise and tenon Fig. 271. Housed tenon joint.

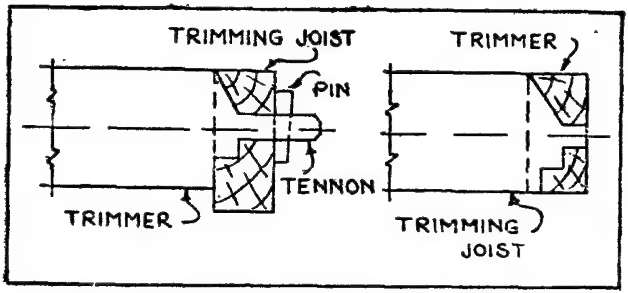
and tenon joint is provided in front of it. The housing may be upto about half an inch to one inch.



Figs. 272 and 273. Tusk tenon joint.

(iii) *Tusk Tenon*—is shown in Figs. 272 and 273. The joists and binders are fixed to heavy girders with the help of a tusk tenon joint. The joists carry load and have to tranimit it the girders. A pin is driven to prevent any lateral movement in the joists or binders. Trimming joist and trimmers are also jointed by the tusk tenon.

The tenon projects beyond the trimming joist and a pin is driven to tighten the joint. See Figs. 274 and 275.



Figs. 274 and 275. Tusk tenon joint mjth pin,

(iv) *Joggle and Tenon* joint is shown in Fig. 276. This is used for fixing the vertical studs of a timber partion to the horizontal sills of the frame.

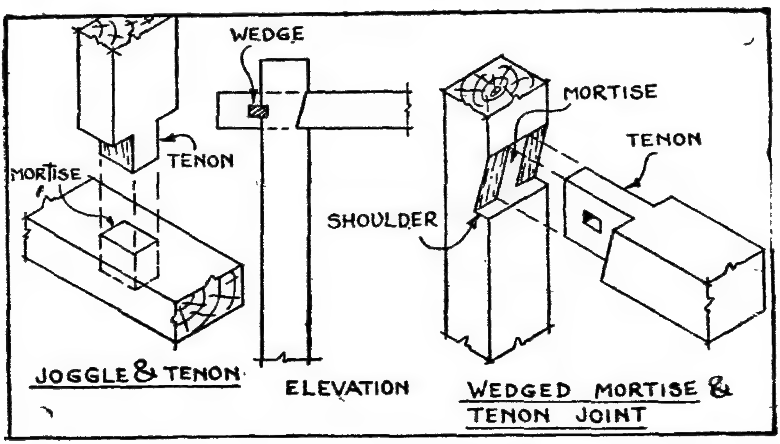


Fig. 276. Joggle and tenon joint. Fig 277. Wedged mortise and tenon with shouldr Fig 278. Wedged mortise and enon; isometric view.

In Fig. 277, is given the elevations. of a *Medged Mortise and Tenon* joint used for timber partitions. The mortise is provided with a shoulder to support the cross piece. The joint is tightened by means of a wedge. The same joint is illustrated in isometric view in Fig. 278.

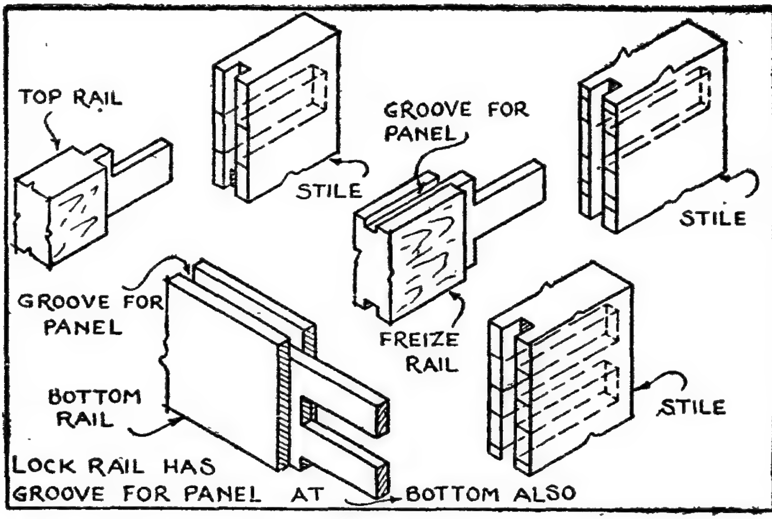


Fig. 279 Framing Joint Haunched tenon, for top rail and stile.
Fig. 280 Framing joint. Haunched tenon; for frieze rail and stile.
Fig. 281 Framing joint. A pair of single haunched tenon.

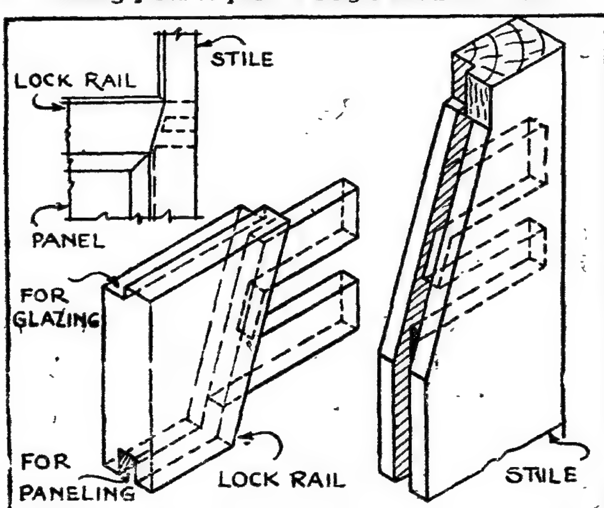


Fig. 282, and 283 Framing joints for lock rail and diminished stile.

(v) *Framing Joints* for door and window shutters. Special types of mrotise and tenon jnints are used for fixing

the rails to stiles for forming frames of door and window shutters. Figs. 279 to 281 indicate such ioints with their details shown in isometric. The thickness of tenon should be one-third the thickness of the piece, and its width should not be more than four to five times its thiceness.

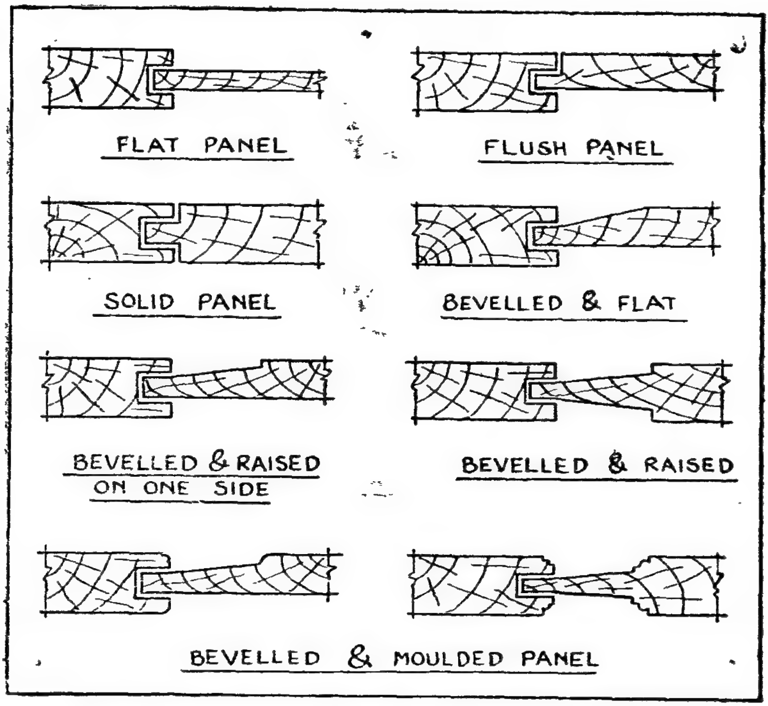
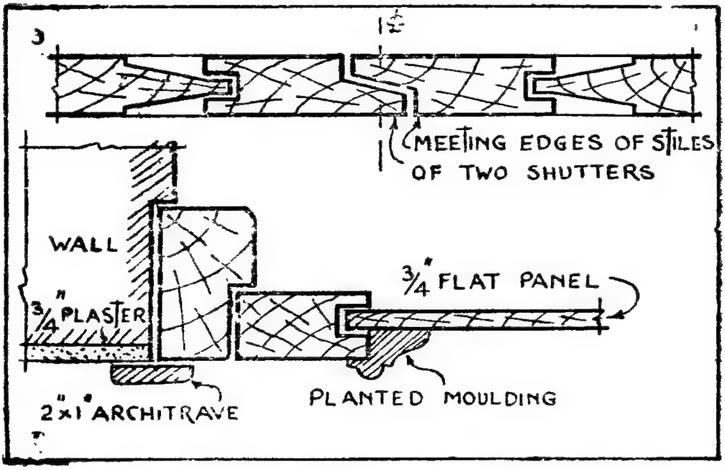


Fig. 284. Flat panel. 285. Flush panel,
Fig. 288. Solid panel. 289. to 280, Raised panels.
Fig. 290. and 291. Moulded panels.

(vi) *Haunched Tenon*, Fig. 279. Used for fixing top rail to the stile. One or two haunches are provided in the tenon to reduce its width, A tenon with two haunches in a freize rail is shown in Fig. 280. A groove is also cut along the piece for the shutter panel to fit in. *A pair of Single Haunced Tenon* is shown in Fig. 281 for fixing the bottom rail to the stile.

When a door has partly glazed and partly panelled shutter the lock rail and the *diminished stile* are jointed as shown in Figs. 282 and 283. This facilitates the top glazed portion of the shutter to be of greater area to admit more light and at the same time the bottom panelled portion can be of normal size and strength.



Figs. 292 and 293. Details of planted mouldings for panels.

Art. 108 Panelling—The essentintial parts in panelling are,—(i) a fame work of stiles and rails; and (ii) a flat board framed into it with a system of grooves along the inside of the frame work. Panelling is very commonly used in doors, partitions, wood encasements and in cabinet making. Only well seassoned wood should be used for such work, as also workmanship should be of a high quality.

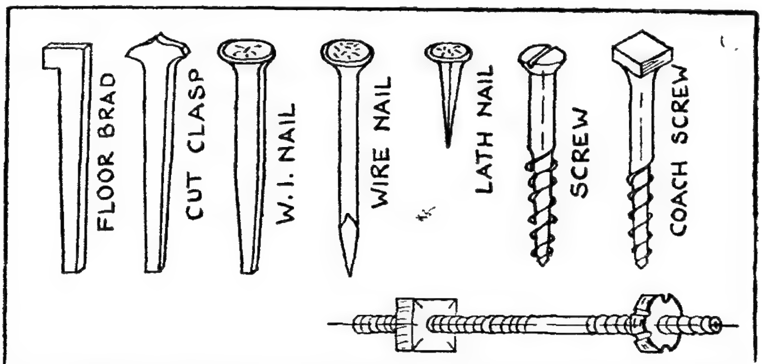
Panelling Varieties—(i) *Flat Panel* shown in Fig. 284, is the simplest of panel. *Flush Panel* and *Solid Fanel* are the other two varieties of flat panel. See Figs. 284 and 215-

(ii) *Raised Panls* are illustrated in Figs. 287 to 289. The panel is given a margin which is slightly at a lower level than the general plane of the panel. The margin is also given a gentle splay.

(iii) ***Moulded Panels***, the varieties of which are shown in Figs. 290 and 291. Moulidings of various designs are provided along the edges of panels and at the junctions of panels and stiles. These mouldings may be either carved on the panels and stiles or may be mounted as shown in Figs. 292 and 293.

Panels are also formed of ply wood of 3 or more plies. These panels are not liable to shrink and are also light in addition to their strength, and durability.

Art. 109. Oblique Joints—For jointing the members in a frame work which meet at an angle other than a right angle, oblique tenon joints are commonly used. Such joints occur in timber roofs and in the frame work of heavy partitions. Sometimes these joints are strenghened by iron straps overlapping them.



Figs. 294. to 301, Various fastenings for wood work.
Fig, 302, Hand--rail screw.

The method of jointing the principal rafter with the tie beam and the inclined strut with principal rafter is shown in the various figures under doors. Oblique mortise and tenon joint is used between the principal rafters and the king post, and king post and inclined struts respectively. It will be seen that the above joints are further strengthened by means of iron straps and bolts with washers.

Various types of oblique mortise and tenon joints are also required in the framework of a heavy timber partition.

Art. 110. Fastenings—The various fastenings for wood work, wrought and put up, are shown in Figs. 269 to 301. They are,—brads, clasps, wrought iron nails, wire nails, lath nails, ordinary and coach screws. Hand rail screw shown in Fig. 302 is used to strengthen a continuous hand-rail at bends.

The use of *Iron straps*, *hardwood wedges* and *keys* for fastening and lengthening a joint has been already discribed under the descriptions of the various joints in the previous chapter.

CHAPTER X

Doors and Windows

Doors and windows-their component Parts. Reveals and jambs. Types of doors-ledged doors, ledged and braced doors; framed and ledged doors; framed and panelled doors: glazed or sash doors; lourved doors, flush doors, Doors without hinges; rolling doors, sliding doors; collapsible doors; revolving doors, casement doors.

Windows:--their component parts, window top and sill Metal casements. Skylights, Lanterns.

Art. 111. Doors and Windows and their component Parts—The two materials of which doors and windows are made are timber and steel, though for glazed portions of shutters glass is invariably used. The modern practice is also to use R. C. C. frames for doors and windows. In the following articles, the detailed methods of constructing teak wood doors are described.

The *Component parts* of a door are,—

(i) A door frame of the required size to fit correctly in the opening formed in the wall; and

(ii) Shutters to fit in the door frame. For small openings single-leafed or single shuttered door is used; and for wider openings, doors with two shutters are used. The two shutters may have each of them fixed separately on either side of the frame, or they may be hung on one side only. with hinges fixed between the two shutters to admit them to be folded. Sometimes doors are provided with shutters on the two sides of the frame, and the inner shutters may be fully glazed or fitted with mosquitto proof wire netting, while the outer shutters are fully panelled.

Raveals and Jambs—The frame of a door is built up in reveals formed in the sides of the opening left in masonry. Reveals are of widths varying from 3″ to 5″. On the opposite

side of the reveal, the jamb is given a splay as previously stated, see Fig. 76, page 78.

Fixing of Door Frame—The frame is fixed in the wall by a hold-fast as shown in Figs. 303 and 309. The hold fast is fixed at its one end to the frame by means of screws, and its other end is opened out to have a grip in masonry. Preferably hold-fasts should be embeded in cement concrete in a wall.

Door Size—The size of a door or a window is usually expressed by the over all dimensions of its frame which corrseponds with those of the opening formed in masonry for the purpose. The minimum height of a door is 6′-3″ and the width 3′-3″, though single shuttered doors serving unimpor-

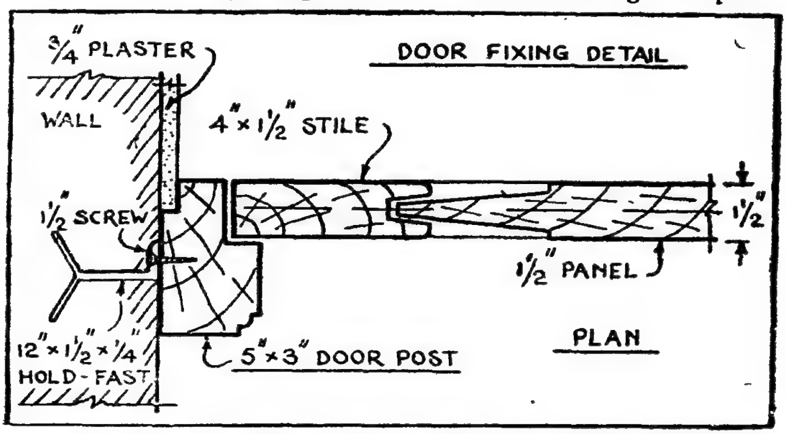


Fig 303. Door frame details. Fixing method.

tant sections of a building could be made 2′-6″ wide. If a door includes a fanlight or a ventilator attached to it on top, its height will be 7′-9″. The maximum size of a door is not usually more than 4′-6″ × 8′-6″.

Door Frame Details—A door frame is formed by jointing vertical posts, a head and a sill. It may be noted that sills are sometimes omitted. The post carries a tenon which fits into the corresponding mortise in the bead or sill. The head and sill project beyond the posts to admit of the frame being fixed into the wall at its ends. These projections are termed as horns.

When the bottom sill is omitted the posts are fixed into the floor below by means of iron dowels, ar shown in Fig. 308 on page 156.

The size of scantling of a door frame may vary from 3″ × 3″ to 6″ × 4″, the thicker dimension being accross the wall. The outer edge is either shamfered or moulded as desired. On the inner edge of the frame, a ½-in. thick rebate or a rectangular recess is formed to receive the shutters. See the same figure given above.

Art. 112. Types of Doors—Doors are classified usually into the following types according to their methods of construction and use,—

(i) Ledged doors.

(ii) Ledged and Braced doors.

(iii) Framed and Ledged doors.

(iv) Framed and Panelled doors.

(v) Glazed or sash doors,

(iv) Louvred doors.

(vii) Flush doors.

(viii) Doors without hinges;—

(*a*) Sliding Doors. (*b*) Rolling Steel Doors.
(*c*) Collapsible Doors. (*d*) Revolving Doors.

(ix) Casement doors.

The salient features and the methods of construction of these types of doors will now be described.

Art. 183. (i) Ledged Doors—A simple method of making a door is shown in Figs. 304 to 306. Battens usually of 6 ins. width and ¾″ to 1″ thick are jointed together to form a door shutter. Tongue and grooved joint should be used to prevent the appearance of splits between the planks. The upright planks are fixed to horizontal rails or ledges which are three in number. viz. top ledge, middle or lock ledge and bottom ledge.

door stops could be fixed as shown in Fig. 306. The shutters are fixed to the frame with the aid of T or garnet hinges.

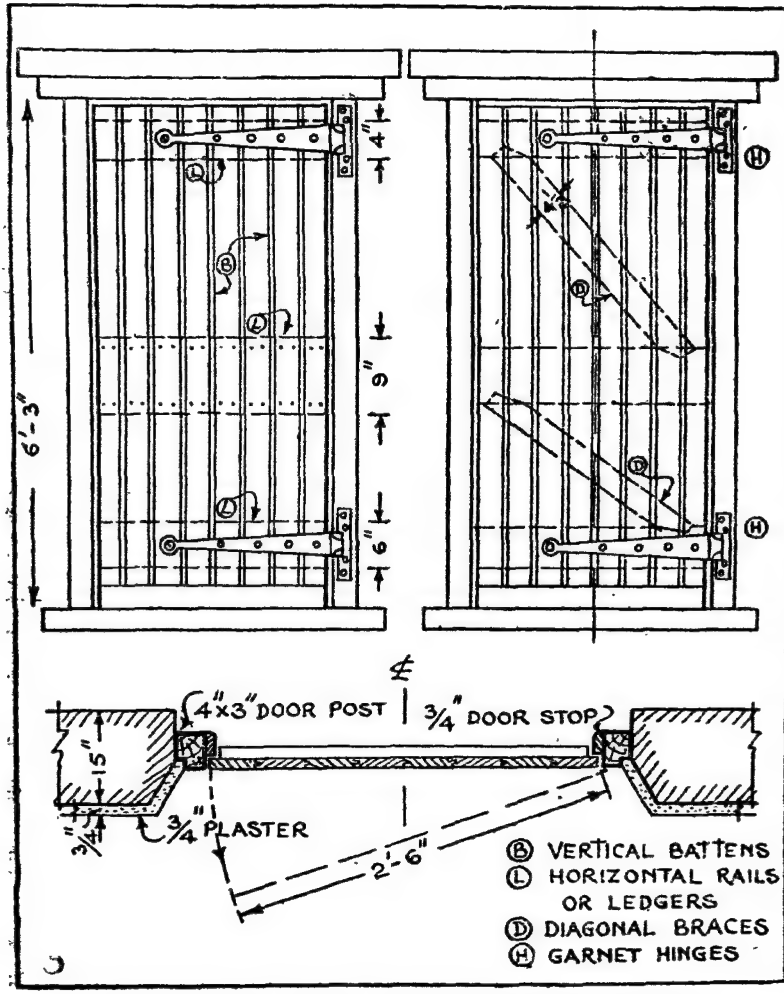


Fig. 304 to 306. Details of ledged and braced doors.

(ii) *Ledged and Braced Doors*—For wider doors, additional diagonal pieces called braces are used between the ledges as shown in Fig. 304. Oblique mortise and tenon joints are used for fixing the braces into the ledges.

(iii) *Framed and Ledged Doors*—A better method of preparing battened doors is to form a frame work, consisting of a top rail and a bottom rail and two stiles. To strengthen the frame and lock rail, braces are also provided. A framed and ledged door is illustrated in Fig. 307. This door is stronger and has a better appearance than tne privious two types of doors of the same class.

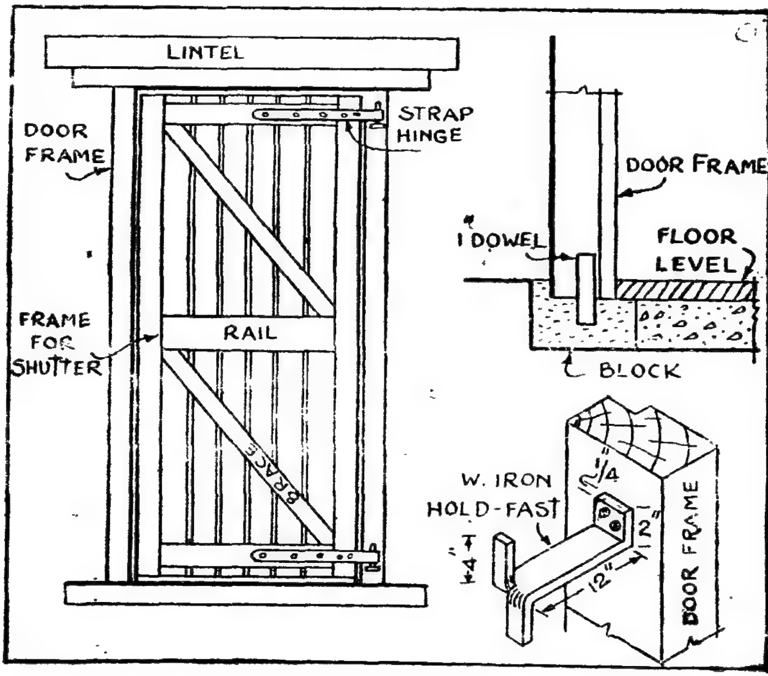


Fig. 307. Framed and ledged door.
Fig. 308. Use of dowel pins in fixing door frame.
Fig. 309. Hold fasts for door frame fixing.

In Fig. 308 is indicated a method of fixing the post or a door frame in the floor, when the bottom sill is omitted. A dowel pin 3/4" to 1", either of hard wood or of iron is used for the purpose,

An isometic view of the details of a wrought iron hold fast and the method of fixing it to a door frame are given

in Fig. 309. Hold fasts should be screwed down to the door frame. They should be embedded in concrete for stength.

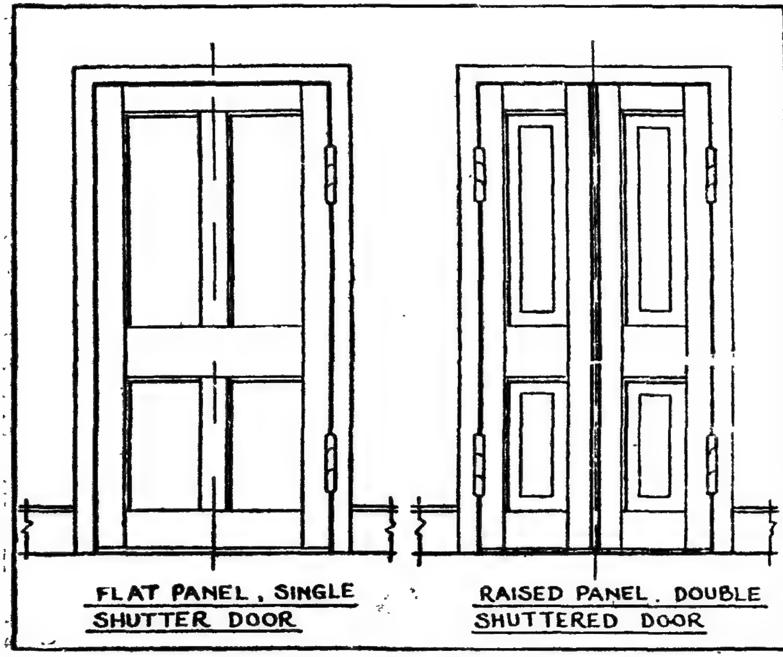


Fig. 310 Four panel, single shutter door.
Fig. 311. Double shuttered, raised panel door,

Art. 114. Framed and Panelled Doors—In Fig. 310 is illustrated a four panelled, single shutter door very commonly used in practice. The door consists essentially of a framing made up of a requisite number of horizontal rails and vertical stiles. A detailed description of panelling has been already given in the previous Chapter, Art. 107. The joinery involved in this connection is also detailed therein.

A double shuttered door with raised panels is shown in Fig. 311. The thickness of the frame for the shutters varies from 1¼″ to 2″. The number of pannels in any single shutter is usually limited to six. In such a case the various horizontal rails are termed as, top rail, bar rail, lock rail

and bottom rail. The central stile is termed mullion or muntin.

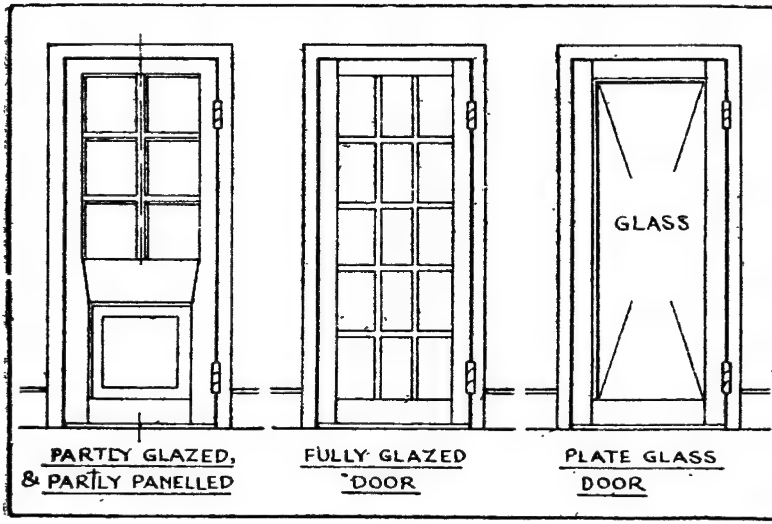


Fig. 312. Partly panelled and partly glazed door.
Fig. 313. Fully glazed door, or sash door.
Fig. 314. Plate glass door.

Art. 115. Panelled and Glazed Doors—Sometimes, when light has to be admitted inside a room, doors have their upper part provided with glazing. The lower portion of the door is panelled as mentioned above. The height of the glazed portion is usually 2/3rd and that of the panelled portion is 1/3rd as shown in Fig. 312. The use of diminished stiles or gun stock stiles on the sides of the shutter frame is also indicated in the above figure. Partly panelled and partly glazed doors also have double shutters. The glasses are fixed in the rebates of the frame-work of sash bars, and they are secured by nails and putty, or by beads bradded to the frame.

In Fig. 313, a fifteen glass-panelled, fully glazed door is shown. In Fig. 314 a door with a single panel of plate glass is shown. These doors are specially suited to light lobbies corridors, halls, staircase landings, show cases etc, and supplement the light ordinarily admitted by windows.

Art. 116. Louvred Doors—If it is intended to allow a free passage of air and at the same time to maintain sufficient privacy in a room, louvred doors as shown in Fig. 315 are provided. A louver is an inclined board fixed in a frame work. To form a door or a window shutter, they are fixed

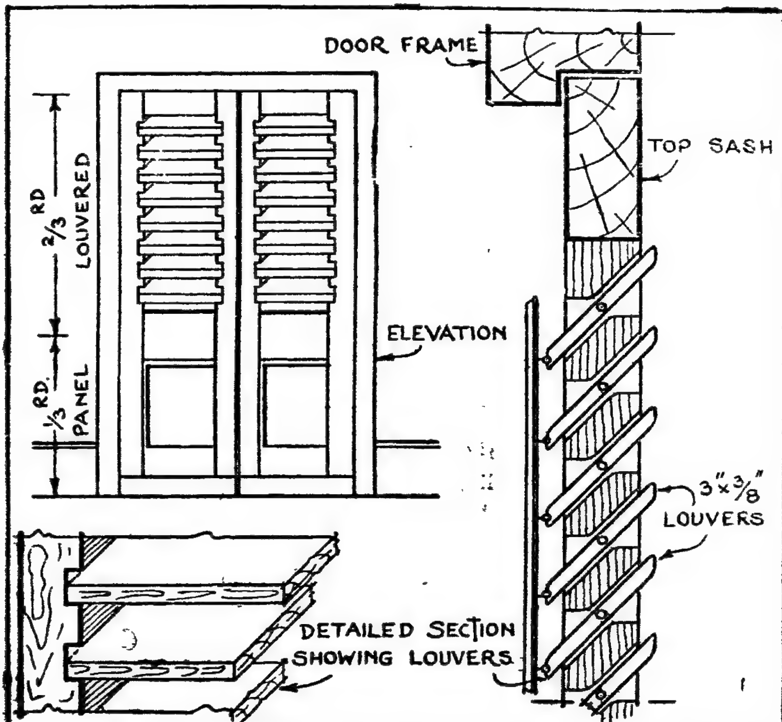
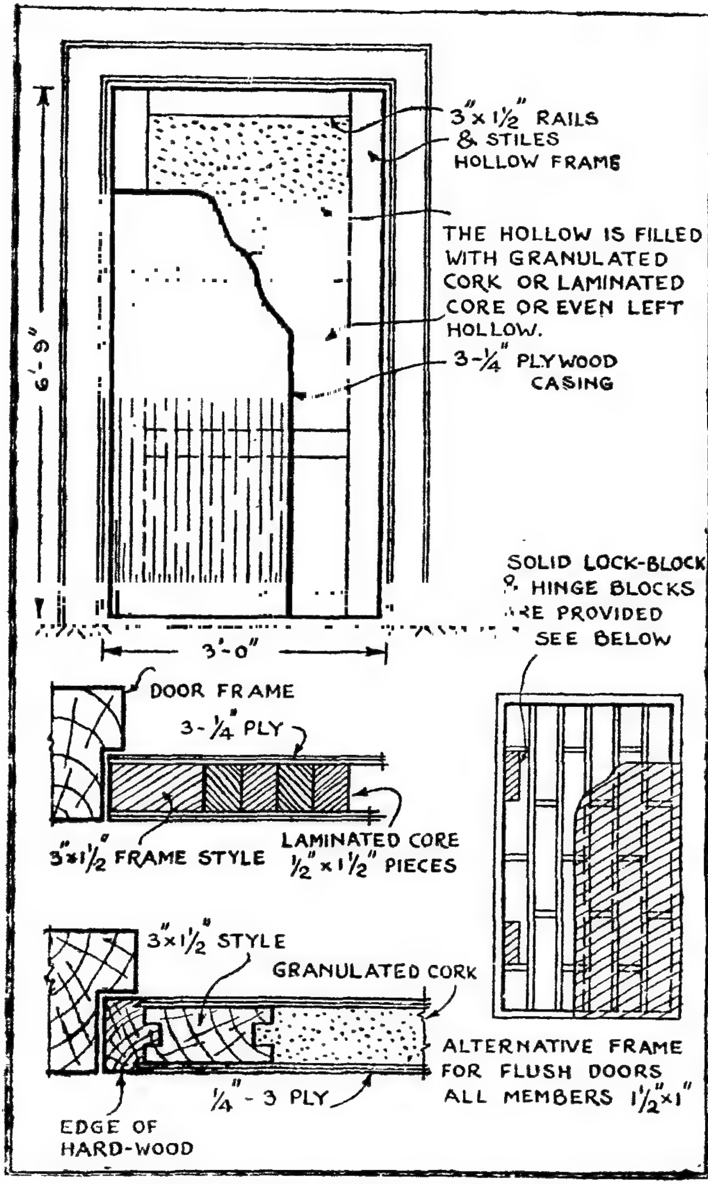


Fig. 315. Louvred Doors. Figs. 316 & 317. Details of fixing louvres.

in a series so that the upper back edge of any louver is above the lower front edge of the next higher louver. See Fig. 316. The usual inclination given to louvers is 45. Sometimes the louvres are attached to the shutter frame by pivots and in addition all the louvres are connected to a common vertical piece of timber with double eyes. This facilitaste to push down or lift up all the louvers, in series, in order to admit light inside the room, and also to obtain a horizontal vision on the other side. See Fig. 317.



Figs 318 to 321. Details of fush dcors

Art. 117. Flush Doors—A flush door consists of a skeleton or a hollow frame of rails, and stiles, covered with

ply wood or any other type of reconstructed wood as shown in Figs. 318. to 321. Flush doors are manufactured in standard sizes to facilitate mass production. The internal hollow panels of the frame work of a flush door may be filled with granulated cork or any light material instead of being left hollow. Sometimes laminated core pieces are also used to fill the hollow space in the frame work. See Figs. 319 and 320. A lock block and a hinge block are also provided to fix a mortise lock and hinges to the shutter. See Fig. 321. Proper marks should be left on the outside to indicate the locations of these blocks. In modern practice of building construction the use of flush doors has become very common. They do not catch dust and are easy to clean, and could be made decorative by the use of proper wood for the facing.

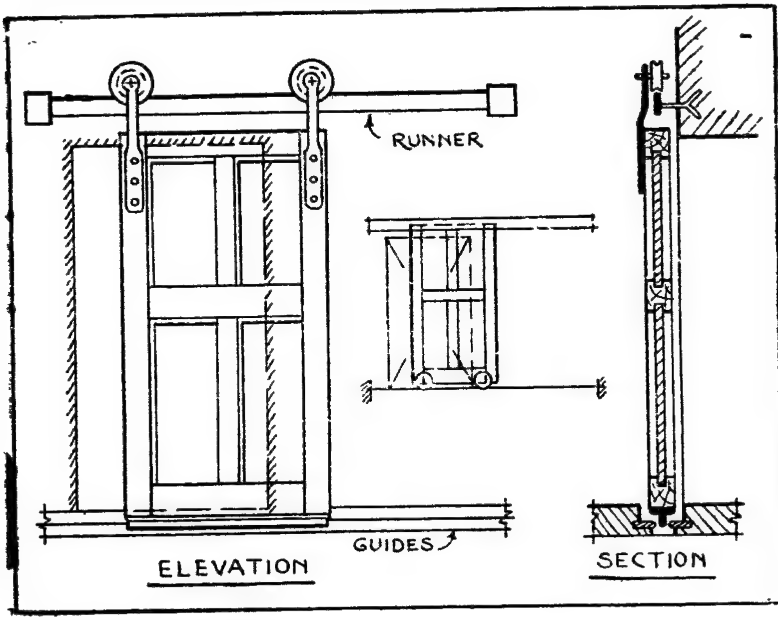
Art. 118. Doors without Hinges—(i) *Sliding Doors.*—The use cf hinges for fixing shutters to frames of doors is eliminated by the use of rolling doors as shown in Figs. 322 to 323. They are commonly used for the entrances of godowns, shops and garages and are moved on horizontal runners. The lower end of the door moves between the guides, which prevents an undue lateral movement in the door.

(ii) *Rolling Steel Doors*—These doors are capable of being rolled up and cause no obstuction while opening by occupying unnecessary floor space. They are commonly used for show-room openings, doors and windows, and for entrances of shops, garages, etc. They are sufficiently strong and offer proper safety to glass and the interior when closed.

(iii) *Collapsible Door*—This is another form of door where hinges are not used for opening and closing the shutters of a door. The door essentially consists of a mild steel frame work of rolled steel sections. Flat iron pieces of $\frac{3}{8}''$ to $\frac{5}{8}''$ wide, $\frac{3}{16}''$ thick are used crosswise and are fixed to vertical flat iron pieces at $4\frac{1}{2}''$ to $5''$ centre to centre apart. Rollers are provided to support the entire door and the door moves on these rollers when being opened or closed.

(iv) *Revolving Doors*—Sometimes revoling doors are

provided where a constant foot trafic of people going in and

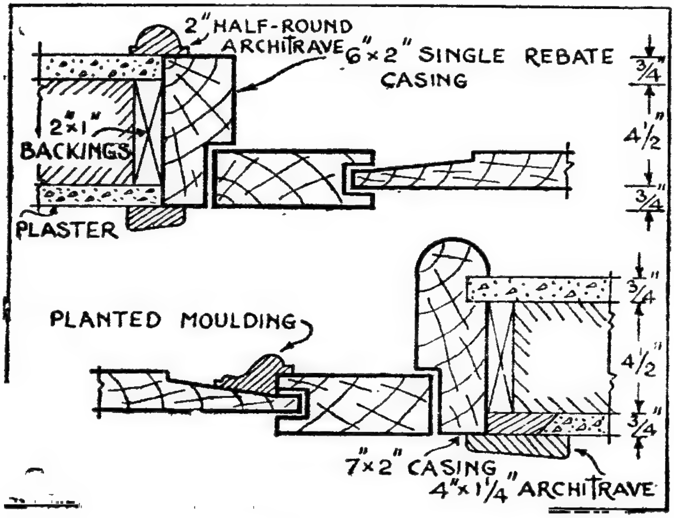


Figs. 322 to 324. Details of sliding doors

coming out of an entrance in a public building has to be handled. These doors keep the opening automatically closed when it is not in use. Usually there are four shutters arranged diagonally on the sides of a centrally placed pivot. A circular space of entrance is also provided into which the four shutters mentioned above revolve. Revolving door also helps to exclude a draught of air through them and are therefore better suited at the entrance of an air-conditioned building.

Art. 119. Casement Doors—For thin partition walls the sides of openings to take the door are often lined by a single board as shown in Figs. 325 and 326. This is intended to provide strong jambs for the door shutters to be fixed. At the junction of the wall plaster and the lining, architsctrave mouldings are provided to improve the appearance at the entrance. The lining is formed out of the solid in one piece and is usually termed as rebate. The side linings

or posts are framed into the head or the top lining by mortise and tenon joints, and the ends of the head are kept projecting 6 ins. beyond the post to enable them to be built into the wall. The posts are fixed to the sides of the openings by means of backings as shown in the above figure. These are termed as "grounds" and serve as foundation for the lining and the architrave.



Figs. 325 and 326. Details of casement doors.

Art. 120. Windows and Their Construction—The various construction aspects and their classification generally follow the principles employed in the making of doors. A fully glazed window with the details of construction showing the frame of the shutter and the method of fixing the sash bars is shown in Figs. 327 to 328. The window shutter is fixed to the window frame by means of butt hinges. In Figs, 329 and 330 the method of providing a cut stone sill to an exterior window is shown.

The following are the constructional terms used—

(i) *Sash Bar*—This is a special type of frame of a lighter section designed for carrying the glass. Sashes consist of horizontal and vertical sash bars fixed in a frame work

as shown in the above figure. They may be fixed, made to slide up or down or sidewise, hung at the top, bottom, or sides, or be pivoted on the central axis.

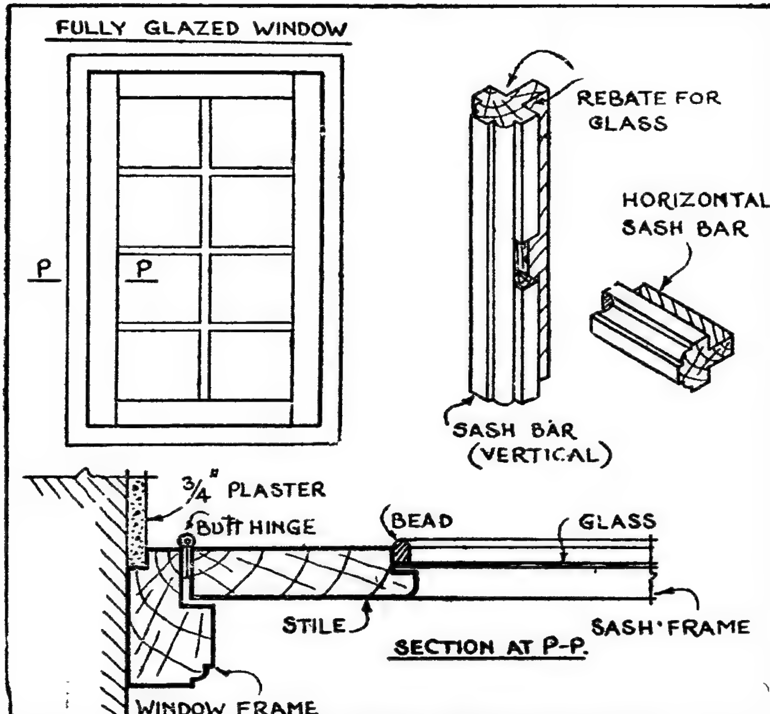


Fig. 327. Fully glazed window. Details of sash bars.
Fig. 329. Glazed window details.

(ii) *Frame*—Sashes are fixed or made to slide in a frame which is either solid or hollow. A solid frame is shown in section in Fig. 330 and similar to the one described in the case door in Art. 102. The frame may carry a single rebate or a double rebate. Sometimes the opening of the frame between the head and the sill is divided into two parts by horizontal picce, called a *Transome*. Very often a transome is employed to separate the main window portion from a fan-light if provided at the top. Mullions are vertical members placed between the two posts and divide a window opening into two or more vertical parts.

(iii) *Boxed Frame or Cased Frame* is employed for sashes sliding vertical, In Figs. 331 to 333 the details of a casement window are shown. Cast iron counter weights are

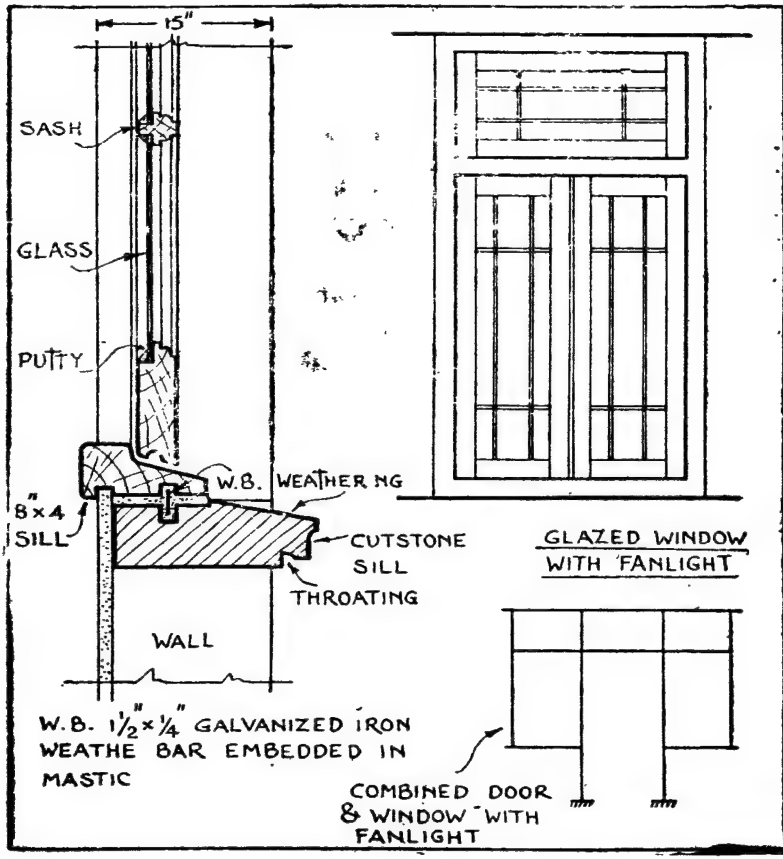


Fig. 329. Window opening. Glased window with fanlight.
Fig. 330. Combined door, window and fanlight.

provided to enable the sashes to slide up or down and a parting bead separates the two sashes.

Art. 121. Windows, Tops and Sills—Special precaution should be taken in providing sound and solid construction work at the top and at the bottom of the window opening, specially in the case of window openings, located in

external walls, since n the latter case the exclusion of rain water from entering inside a building has to be

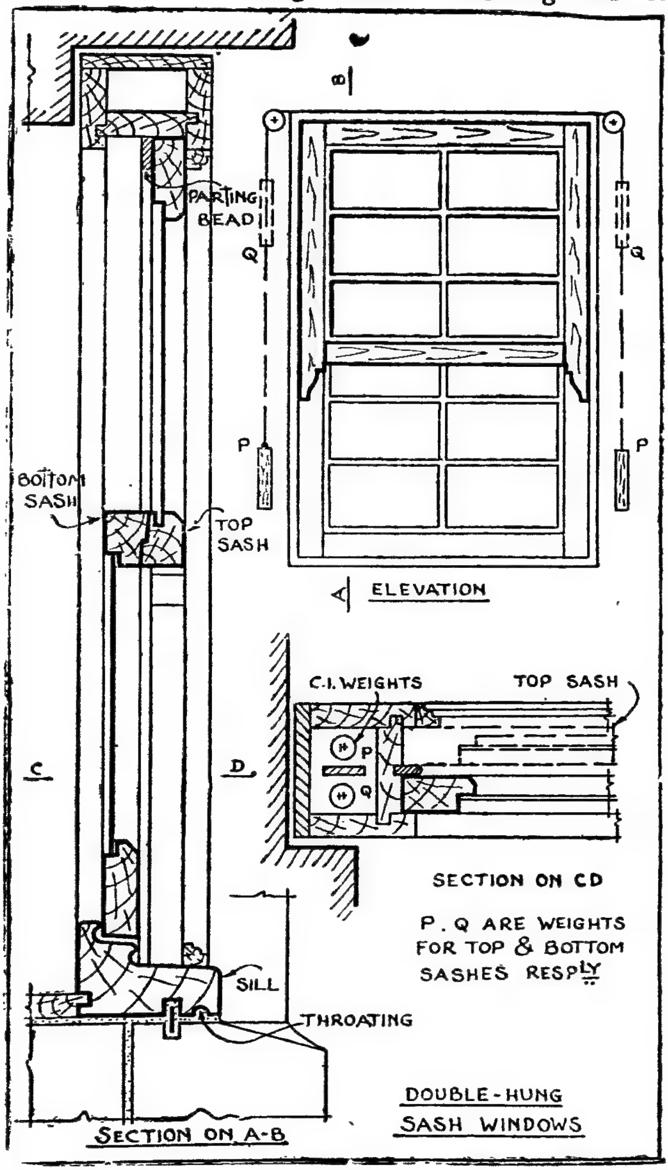
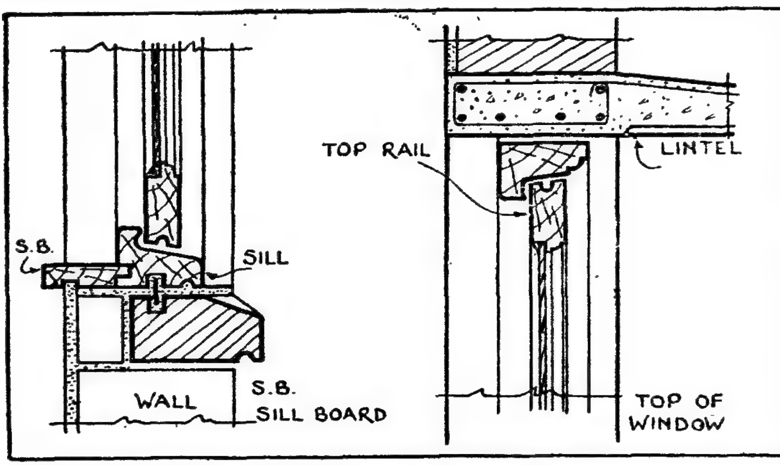


Fig. 331, 332 and 333. Details of double-hung sash window.

attended to as in Fig. 334. A cut stone sill is shown with a weathered top and a drip moulding. A water bar is placed vertically between the cut stone sill and the wooden sill of the window frame to prevent the water from entering through the joint.

In Fig. 335 the top of the opening is provided with a R. C. C. lintel which is cast monolithic with a chajja or a sunshade. In this case the window sashes open outside.



Figs. 334. Detail of window sill. Fig. 335. Details of p

Art. 122. Metal Casements—In modern practice metal sashes and frames are generally used for all classes of building but their use for public building has become very common. Metal sashes can be fixed into wooden frames as shown in Fig. 336. or into a stone sill with the aid of a screw and a hard wood plug as shown in Fig. 338. Metal sashes and sash frames are made of light rolled stections of angle, tee, or channel, though some proprietary types adopt a combination of these sections. The glass is held in position by a metal pin and putty is applied at the joints as before. Metal windows cerrode very quickly and therefore require to be preserved by paintng before fixing and also at intervals subsequently.

Art. 123 Skylight–Skylights are provided to admit light from a roof. They are fixed specially in sloping roofs and also serve to secure ventilation in addition to admitting light. The details of a typical skylight are shown in Fig. 339. The common rafters are trimmed as mentioned later in roofs.

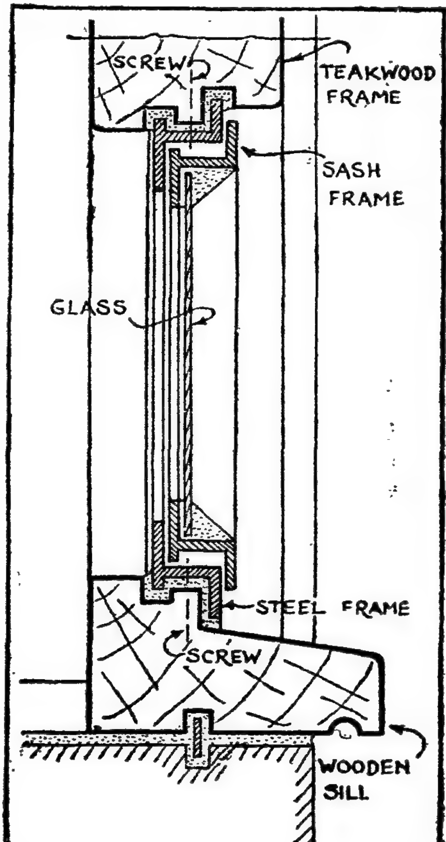
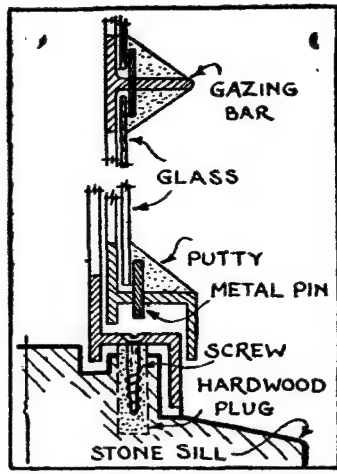


Fig. 335. Metal casements with teak wood frame.

On the four sides of the opening, 2″ thick and 9″ to 11″ deep curbs of tinings are provided to form a solid frame known as the curb frame. On top of the curb a sash is provided lining are provedd to from a solid frame known as the curb for fixing the skylight glass and is made to project beyond

the curb frame. Lead flashiug is fixed on the outside of thecurb frame to form a gutter to direct the rain water around thesky light.

Art. 124. Lanterns—Lanterns or Lantern lights are windows fixed in a flat roof for admitting light. They project above the normal surface of the roof. They are also fixed across the ridge of a roof. They are provided for lighting passages or interior section of a building where normal lighting cannot be secured by window. Sometimes ventilators are provided at the sides of a lantern light.



F gs. 337 and 333. Metat casements in metalframes

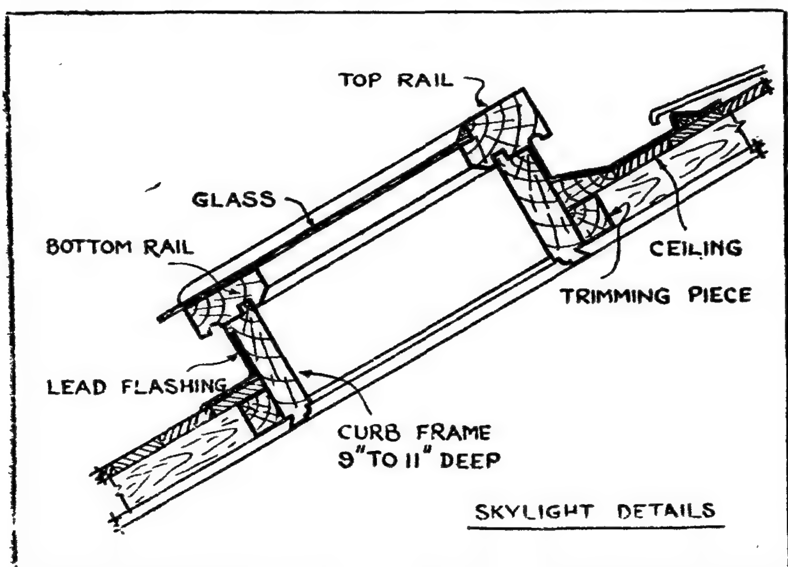


Fig. 339. Skylight details.

CHAPTER XI

Timber Floors

Ground floors--concrete and murum, Upper floors --structural aspects. Single floors, Illustrative problem. Double floors. Methods of fixing joists, to binders, Illustrative problem. Framed floors, Illustrative problem, Advantages and disadvanteges of different floors.

Openings in timber floors. Fire place openings, Flooring and floor boards, Heading joints, Strutting of joists--hering-bone and solid strutting. Floor ceilings: closed and open ceilings, Ceiling joist-Ground floors of timber and sound proofing.

The provision of floors to buildings and the principles under–lying their construction, together with the methods and materials used will now be considered.

Art. 125. Ground Floors—These include all floors built at the plinth level at a suitable height above the surrounding ground. Unless accompanied by a basement floor, a ground floor usually rests on a fillng of murum or well packed rubble and murum above the ground level. On this compact filling, a layer of concrete either of lime or of cement, and of a thickness varying from 4½ ins. to 6 ins. is laid and the surface of this layer is finally finished as explained later. Fig. 340 gives the details of constructicn of such a floor. It is necessary to ensure that the filling is thoroughly rammed, as otherwise uneven settlements occur subsequently, resulting in the fomation of irregular cracks in floor finishings.

In damp foundations, ground floors are constructed with special precautions by introducing a damp-proof course and making the floor concrete slightly water-proof by the grading of aggregate and adopting various integral methods.

Murum Floors–In the case of ground floors of unimportant buildings, the layer of concrete and the special finishing of surface are omitted. Instead, a well selected and screened layer of murum is laid in tnickhess of 3 ins. for the top 12

ins. These layers should be properly watered and rammed. Small quantities of chopped straw is often mixed with murum to prevent the formation of cracks.

Upper Floors.

Art. 126. Structural Aspects—*Classification of Floors*—Wooden floors are classed into three main types as follows,—

(i) Single floors;

(ii) Double floors; and

(iii) Framed floors.

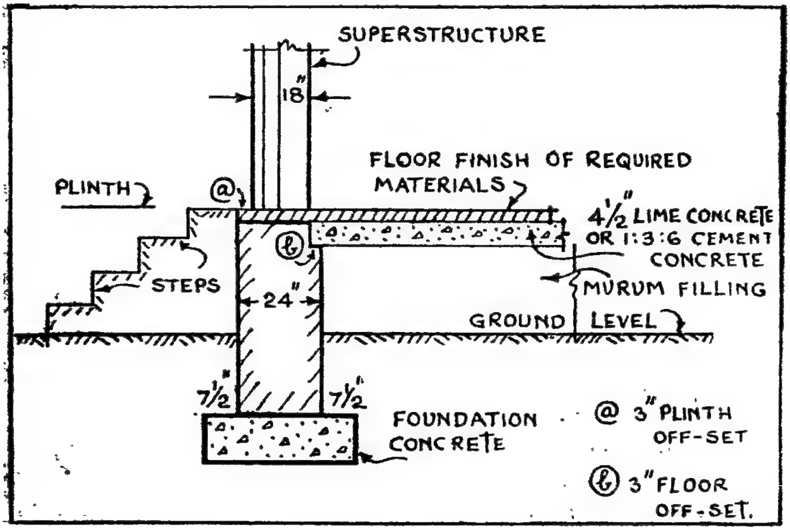
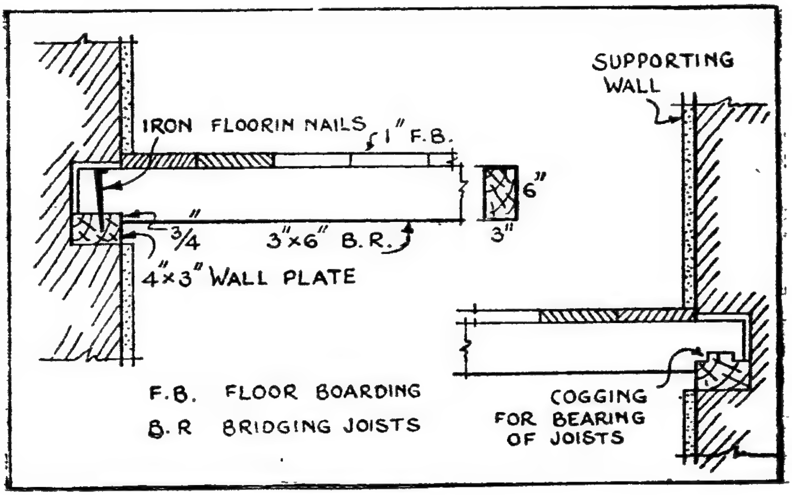


Fig. 340 Details of ground floor.

Component Parts. From the structural point of view these floors are treated as consiting of two parts,–one part comprisingof the supporting members which are joists,binder and girders as required, and the other part, of floorboarding which is laid on top of the first. Sometimes a ceiling is also provided at the underside of supporting members. During construction the supporting members are placed first and the floor is then termed as *naked floor.* When all the rough work

of construction is over, the floor boarding is fixed. The ceiling may be fixed subsequently or before the floor boarding is laid

In all wooden floors, the floor boards rest directly on the joists which are commonly known as *bridging joists.* These are timber supports, and the strength and rigidity of floors depend on these supporting members. For bigger rooms, binders and girders are employed to support the bridging joists as described later.



Figs. 341 and 342. Details of single floors. Wall plates. joists and flooring boards.

Strength and Rigidity—It should be remembered that a member which is strong is not always rigid and *vice versa.* The strength of a member indicates its capacity to carry a load without over-stressing the material, whereas its rigidity relates to its capacity for resisting deflection or sag under a load. Floors which are not strong will yield under loads by a failure in the material, as also floors that are not rigid enough will vibrate as pepole walk on them and hence they are not comfortable to use.

Art. 127. Single Floors—These floors consist of light joists, commonly known as bridging joists laid across short spans of rooms, and are covered with a finishing surface consisting of floor boarding. The economical span for the

Table No. VIII

Safe Spans for Floor Joists.

Spacing at 15 ins. c/c $E = 1.2 \times 10^6$ ibs/sq in. $f = 1000$ lbs. sq. in.

Size ef josit it s x ins.	Span in feet for Max fletural strength				Span in feet for stiffness			
	Live load. lbs./sq ft.				Live load./Sq. ft.			
	40	60	80	100	40	60	80	100
2×6	10'–0"	8'–6'	7'–0"	7'–0"	10'–0"	8'–6'	7'–0"	6'–6
2×8	13'–0"	11'–0"	10'–0"	9'-6"	13'–0	11'–0"	9'–6"	9'-0
2×10	16'–0"	14'–0"	13'–0"	12'–0"	16'–0	14'–6"	12'–0'	11'-0'
3×6	11'–6"	10'–0"	9'–0"	1'–0"	12 c	10'–6"	9'-0"	8'–0'
3×8	15'-9"	13'–0"	12'–0"	11'–0"	16' – 6	14'–6"	12'–0"	11'–0"
3×10	19'–0"	16'–6"	15'–0"	14'–3"	20' – 6	17'–6"	15'–0"	14'–0"

joists of a single floor varies from 6 ft. to 10 ft. but spans upto 12 ft. are also sometimes covered by bridging joists to from single floors. If the joists:–are of steel they con be of much greoter length than timber joists, as could be seen under "steel and concrete floors" described later. The convenient size for timber joist varies from 6" x 2" to 10" x3", spaced usually at 12" to 16" centre to centre, Details about the methods of consturucting single floors are showu in Figs. 341 and 342.

The joists rest on *wall plates* at their ends and a notch of ½ in is provided here to hold them in position. In addition, square nails of the required length are also driven, one at each end. Sometimes cogging is provided for bearing of joist. The ends of joists should not touch the wall, but should leave a clearance of about 2 ins. Wall plates, in addition to distributing the load on the walls,help to secure the ends of bridging

joists on the wall. They are usually of size 4″×3″ to 6″×4″ and are placed with their greater dimension horizontal.

In the accompanying Table No. VIII are given spans for the different sizes of joists ranging from 2″ × 6″ to 3″ × 10″, for maximum flectural strength and maximum stiffness. The values of stress and modulus of elasticity for timber are taken as 1000 lbs-/sq. in. and 1.2×10 lbs/sq. in.

Art. 128. Illustratjve Problem—Calculate the size of timber joists for a single floor to span a width of 8′–0″. Permissible stresses in timber in tension and in compression, f and c are, each equal to 1000 lbs./sq. in. Modulus of elasticity for timber is 1.5 × 10 lbs./sq. in. The joists are spaced at 12 ins. apart. Permissible shear stress in timber is 80 lbs/sq. in. and deflection $\frac{1}{360}$ of the span.

Solution—

(1) For Residential Buildings,

Loads

Live load	50 lbs./sq. ft.
Dead load due to floor and joists	30 lbs./sq. ft.
Total load, W =	80 lbs./sq. ft.

Since the joists are at 12 ins. c/c, the load on each joist is 80 lbs/sq. ft.

If l is the effective span of the joist in feet, then the bending moment at its centre, equals,

$$\text{B. M.} = \frac{wl^2}{8} = \frac{80}{8} \times l^2 = 10\,l^2 = 10\,l^2 \text{ ft. lbs.}$$

$$= 120\,l^2 \text{ in. lbs.}$$

For all practical purposes, a joist of $b = 2$ ins. width is enough. The required depth d, can now be calculated as follows,

$$\text{B. M.} = fz, \qquad \text{where } z = \tfrac{1}{6}bd^2.$$

the section modulus is in³. b and d, the breadth and depth are in inches.

$\therefore\ 120\, l^2 = 1000 \times \frac{1}{6} \times 2d^2$

i. e. $d^2 = \dfrac{120 \times 6}{1000 \times 2}\, l^2 = 0.36\, l^2$

or, $d = 0.6\, l$; l in feet ... ...(1)

In the present case,

$d = 0.6 \times 8 = 4.8$ inches.

$\therefore$ Size of joist is 4.8″ × 2″

If the joists are placed at 14 ins. c/c apart, then load on each joist $= \frac{14}{12} \times 80 = 94$ lbs./sq. ft.

Depth of the joist $= \sqrt{\frac{14}{12}}.\ 0.6\, l = 0.65\, l$ ...... (2)

$= 0.65 \times 8 = 5.2$ inches.

$\therefore$ Size of joist is 5.2″ × 2′.

(II) *For Office Buildings—*

Total load, W = 80 + 30 + 110 lbs./sq. ft. If the joists are at 12″ c/c, then for a span of 8 feet, bending moment at the centre of joist equals,

B. M. $= \frac{1}{8}.\ 110 \times l^2 \times 12 = 165 l^2$ in. lbs.

If a section ot 2″ width for the joist is adopted, then

$d^2 = \dfrac{163 \times 5}{1000 \times 2} = 0.495\, l^2$ as before,

Or $d = 0.7\, l$; l in feet (3)

$\therefore$ Size of joist is 5.6″ × 2″,

If the joists are placed at 14″ c/c apart, we have

$d = \sqrt{\frac{14}{12}}\ 0.7\, l = 0.755\, l$ (4)

$= 6$ inches.

$\therefore$ Size of joist is 6″ × 2″.

Note—In the above example we have assumed a constant width of 2 inches for the joists. But considering the greater loads the bigger spans have to carry, it is better to increase their width with the span; e, g. for spans of 6′-0″, 8′-0″,

and 10--0", the width of joist should be 2", $2\frac{1}{2}$" and 3" respectively.

Shear Stress in Joists

The load carried by each joist in (1) above is $80 \times 8 \times 1.167 = 750$ lbs. where the joists are spaced at 14 ins. c/c.

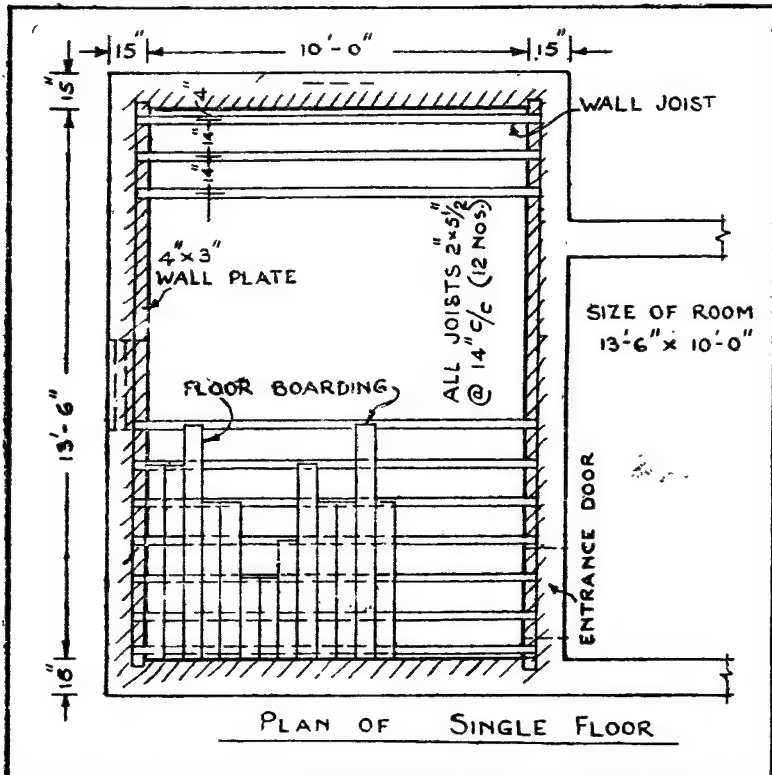


Fig. 343. Construction details of a typical single floor,

Since half of this load is carried by each support the shear stress in the joists near the support, equals,

$$S = \frac{3}{2} \times \frac{1}{2} \times 750 \times \frac{1}{2 \times 5.2} = 54 \text{ lbs. /sq, in.}$$

which is less than the permissible value of shear stress in timber. See Fig. 343 for details of single floors.

Art 129. Advantages of Single Floors—Single Floors are very simple and easy to construct. For a given quantity of timber to construct a floor, they are the strongest and the cheapest. As they lie entirely on the wall upon which they rest, the floor load is distributed equally on that wall, an advantage usually claimed by walled structures.

Disadvantages–For greater spans, single floors require deep joists which consequently increase their wight and cost. Usually when the span exceeds 12 to 15 feet, if they are designed only for their strength, their depth becomes less and therefore they are liable to bend and sag. This also cracks the ceiling below the wall, if ceilng is provided. When openings have to be made in the floors, they require a good deal of trimming. They rest equally on the walls over doors, windows and openings, so that the weak portions in the wal s are loaded to the same extent as the strong portions. They require the use of wall plates to be built in the wall for the whole length of the long sides. In addition, single floors allow the passage of sound from floor to floor.

Art. 130. Double Floors–If the width of a room is more than 10 to 12 feet and a timber floor has to be used, the method of construction is to adopt a double floor. In this case the longer side of the room is sub-divided into one or more shorter spans with the aid of binders as shown in Figs. 346 and 347 thus forming two or more panels. In these panels single flooring is arranged as given in Art. 118.

The span between the binders is usually kept at 6 to 8 feet. Tne ends of binders should rest on templates which may be either of stone or of concrete to distribute the load on the wall. They should not normally rest over openings in walls; but when this could uot be avoided, lintels or beams properly desingned to take the loads of binders should be placed over the openings.

Art. 131. Methods of Fixing Joists to Binders—In one method notcnes are provided on top of the binders and

the joists rest in these notches as showen in Fig. 344. By this method the binders are weakened since their section is reduced by cutting the notches in the compression side.

In another method, the ends of joists are cut and additional fillets are provided along the sides of the binder to support them. This is a better method than the first one. See Fig. 345.

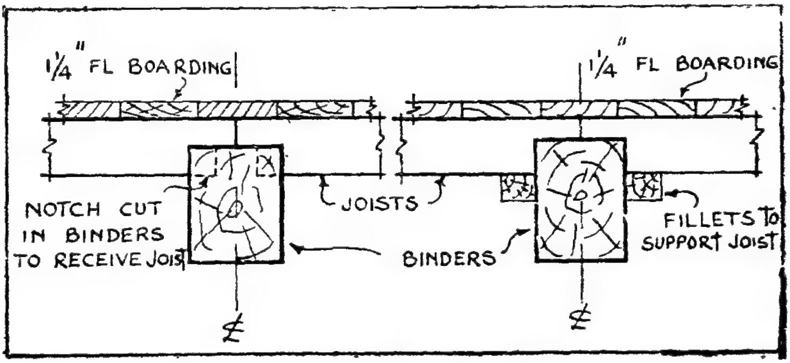


Fig. 344. Joists resting in notches in the binder.
Fig. 345. Joists are cut and rest on fillets,

Art. 132. Advantages of Double Floors—The load on the binder is usually great so that their economically designed section provides for a depth which is often enough to keep deflection within practical limits. Thus double floors are generally rigid. Plaster ceillngs are not liable to crack. The transmission ofsound between floors is also very much less effecfive. If a wall consists of many openings double floors provide a sound construction. since the binders could then be made to rest on the pillasters between the openings and thus leaving weak parts free from load.

By provididg additional binders close to the walls, the ends of joists could be made to rest on them instead of being built into the wall. This protects the timber from decay by keeping the flooring timber out of masonry, which is an advantage under damp conditions.

The *Disadvantages of Double Floors* are mainly due to

extra labour and complications involved during their construction, and also due to the cutting away of the tops of binders for providing notches to receive the joists.

The depth of the floors is increased by the joists resting on the binders. This reduces the available head room in the lower floor. Alternatively for a fixed head room, the height of walls has to be increased and consequently the cost of the building is also increased.

Art. 133. Illustrative Problem— It is required to provide a double floor for a room in a residential building. The room measures 18′ – 0″ × 16′ – 0″. The relevant data to be taken from the illustrative problem given for single floors; Art. 128, page 175.

The problem is solved in two cases :—

Case (A) One binder is placed centrally on the two long walls, thus dividing the room into two panels of 16 × 9 each.

Case (B) Two binders are placed on the long walls dividing them into three equal parts. In this case three equal panels are formed, each of 16′ × 6′.

Solution—

Cases (A) Span for joists is 9′ – 0″, spaced @14″ c/c.

(i) *To determine the loads and bending moment*—The procedure is to design the binder for strength and then to test the section for rigidity.

Total load on each joist = 9 × 94 = 846 lbs. of which half is taken up by the wall and the other half by the binder on which it rests. The joists are at 14 ins. apart and there will be 14 Joists in each panel. The centres of the joists near the wall are at a distance of 5 ins. from it. See Fig. 346.

∴ Load on binder at each point where the joists from the two adjacent panels rest, equals $\frac{1}{2} \times 846 \times 2 = 846$ lbs. But the load on the joists near the wall is slightly less so that they transmit only $(7 + 2.5)\ \frac{80}{12} \times 9 = 64 \times 9 = 576$ lbs. to the binder, at each end.

Total load on the binder,

$$W = 2 \times 576 + 12 \times 816$$
$$= 1152 + 10458 = 11610 \text{ lbs.}$$

Add self load of binder, 10″ × 18″ size assumed,

$$10 \times 18 \times 56 \times 16 \times \tfrac{1}{144} = \quad 1120 \text{ lbs.}$$

Total inclusive load = 12730 lbs.

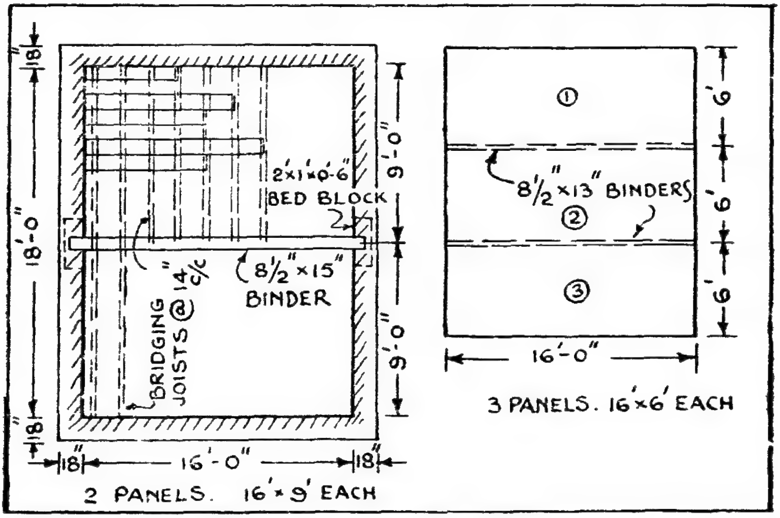


Fig. 346. Double floors. Two panels of 18' x 9' are formed. Fig. 347. The same room with three panels of 18' x 6' formed.

As the joists are quite close to each other, the above inclusive load of 12730 lbs. will be treated as distributed load taken up by the binder. Thus the maximum bending moment is given by,—

$$B.\ \mathbf{M.}\ (\max.) = \tfrac{1}{8} \times 12730 \times 16 \times 12$$
$$= 3{,}05{,}500. \text{ in. lbs.}$$

(ii) *To Calculate the size of Binder.* As before we have section modulus given by, —

$$\tfrac{1}{6}\ bd^2 = Z = \frac{B.\ M.}{f}$$
$$= \frac{305500}{1000} = 305.5 \text{ in.}^3$$

or $bd^2 = 305.5 \times 6 = 1833$ in.^{3}

It should be noted that the width of a binder should be sufficient to receive the joists from both the panels. Usually 6 inch width is enough. This width is increased in the case of binders carrying heavy loads, and bridging across greater spans. While specifying the size of a binder, the ratio between its depth and width should be kept between $1\frac{1}{2}$ and $2\frac{1}{2}$.

For a width $b = 6$ ins. the depth of the binder in this case, is given by,

$$d = \sqrt{\tfrac{1}{6} \times 1833} = \sqrt{306} = 17.5 \text{ ins.}$$

The ratio between d and b is nearly 3 which is rather high.

The following trial sizes for the binder are written down to suit the value of bd—

(u) $10 \times 18^2 = 10 \times 324 = 3240$ in.^{3}
(b) $9 \times 16^2 = 9 \times 256 = 2304$ in.^{3}
(c) $8 \times 15^2 = 8 \times 225 = 1800$ in.^{3}
(d) $8\frac{1}{2} \times 15^2 = 8\frac{1}{2} \times 225 = 1913$ in.^{3}

From the above trial sizes, the adopted size of binder is $8\frac{1}{2}'' \times 15''$.

Weight of the binder is 62 lbs./r. ft., which is not much different from its assumed weight.

(iii) *Test for Regidity.*

$$\text{Deflection, } d = \frac{5}{384.} \cdot \frac{12730 \times 16^3 \times 12^3}{1.5\times10^6\times\frac{1}{12}\times8.5\times15}$$
$$= 0.332 \text{ inch.}$$

This is equal to $\dfrac{0.332}{16 \times 12} = \dfrac{1}{580}$ of span, which is well within the limit to maintain rigidity of the floor.

(iv) *Test for Shear Stress.*

$$\text{Shear stress, s} = \frac{3}{2}\times\frac{12730}{2}\times\frac{1}{8.5\times15}$$
$$= \mathbf{74.8\ lbs./sq.\ in.}$$

which is permissible.

(v) *Bed Block* to support binders on walls. Load at the end of each binder equals, $\frac{1}{2}\times12730 = 5365$ lbs. $= 2.83$ tons.

The bed blocks should be for the full width of the wall preferably. Adopting a size of block as 2'-0" × 1'-0" × 6'-6", as shown in the figure, the stress in the wall masonry equals,

$$\text{stress} = \frac{2.83}{2} = 1.42 \text{ tons/sq. ft.}$$

The bed block may be either of cut stone or of cement concrete as already mentioned.

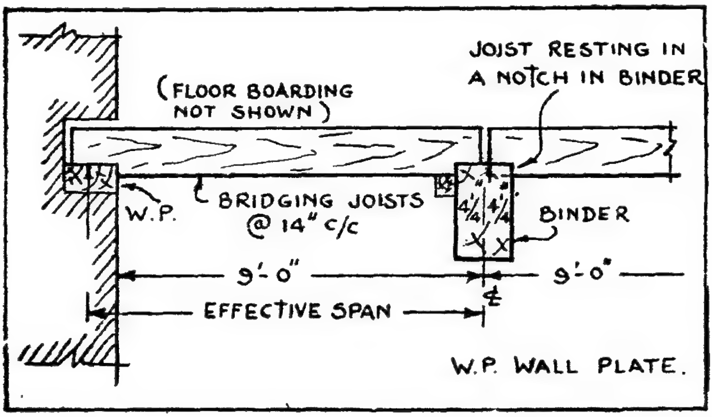


Fig. 348. Double floor details showing the method of construction.

Note—Assuming that the binder rests for a length of 8½" on each bed block, the bearing stress in timber, where it rests equals,

$$\text{Bearing stress} = \frac{6365}{8.5 \times 85}$$

$$= \mathbf{87.5\ lbs./sq.\ in.}$$

Art. 134. Case (*B*)—*See Fig. 347*. Usinig two binders, span for the joists is $\frac{1}{3} \times 18 = 6$ feet. Spacing the joists at 14 ins. c/c as before and adopting a width of 2" for them, the depth required equals $0.65 \times 6 = 3.9$ ins. say 4 ins.

∴ Size of joist is 2"×4".

Floor load on each binder, calculating on the load area supported by it, equals,

$$6'\text{-}0'' \times 16'\text{-}0'' \times 80 = 7680 \text{ lbs.}$$

Self load of binder assumed, size $8'' \times 12'' =$ 597 lbs.

Total inclusive load = 8277 lbs.

$$\text{B. M. (max.)} = \tfrac{1}{8} \times 8277 \times 16 \times 12$$
$$= 1{,}98{,}600 \text{ in. lbs.}$$

$$\therefore bd^2 = \frac{1{,}98{,}600}{1000} \times 6 = 1192 \text{ in}^3$$

Trial sizes for the binders can be written down thus,—

(*a*) $8 \times 12^2 = 8 \times 144 = 1152$ in.^{3}

(*b*) $8 \times 13^2 = 7 \times 169 = 1235$ in.^{3}

(*c*) $7 \times 14 \quad = 7 \times 196 = 1572$ in.^{3}

(*d*) $8\tfrac{1}{2} \times 13^2 = 8\tfrac{1}{2} \times 169 = 1437$ in.^{3}

Adopted size $8'' \times 13''$

Weight @ 43 lbs/*r*. ft.

Tests for deflection and shear stresses, and the design of bed blocks for each binder can now be made on the same line as detailed above for a single binder.

Note—The advantages of using smaller spacings for binders are,—

(i) Binders of smaller sections could be used. These are cheaper than binders of heavy sections.

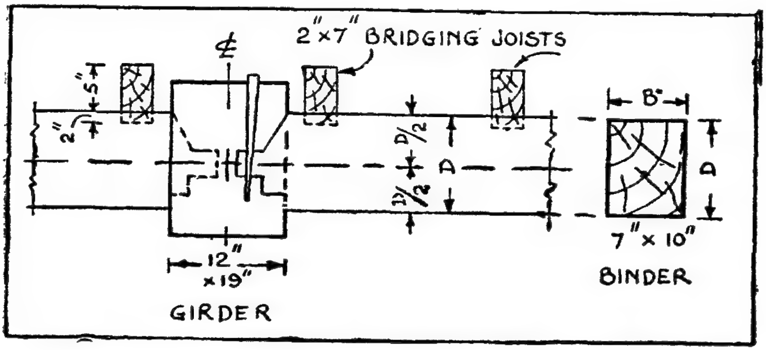
(ii) More headway is available by using binders of smaller depths.

(iii) By using more binders the span for the joists also becomes less and consequently lighter sections could be more economically used for the joists.

(iv) Floors formed by placing the binders at a closer spacing are more rigid.

In the case of timber sections which are heavy, there are more possibilities for the inclusion of hidden defects in their interior; and thus there is a factor of uncertainity regarding their strength.

Art. 135. Framed Floors:—In the case of big halls having spans, of say 22 feet and above, even in their shortest dimensions, framed floors are adopted. Girders are used across the short span to support binders, and they are usually of a very heavy section. To avoid the loss of headway and to minimise the heights of buildings, binders are framed into girders instead of directly resting on them. See Figs. 349 and 350. Tusk tenon joint is used for framing the binder into the girder. Note the method of resting the bridging joists also on the binders in the above figure.



Figs. 349 and 350. Framed floors. Details showing the method of framing binders int girders.

It should be remembered that two binders should never be framed into the girder at one place from the opposite sides as this would mean the weakening of the girder greately. The binders should be framed at a sufficient distance apart in a staggered fashion, as shown in Fig. 351. A spacing of 10 feet is generally found enough for the girders.

Another method of fixing the binders to the girders without cutting the later is to employ on iron stirrup which has a support to receive the binder. The iron stirrup is secured to the girder by bolts. In such a case it is necessary that two adjacent binders should be fixed to the girder at one and the same place to balance the load taken by the stirrup.

Art. 136. Illustrative Problem—Design a suitable framed floor for a hall measuring 30'-0" × 24'-0". Show also a method of providing ceiling to the above floor.

Solution—

Considering the large size of the hall, it will, be assumed that the live load coming on it will be similar to that in an office building. The general arrangement of flooring is shown in Fig. 351.

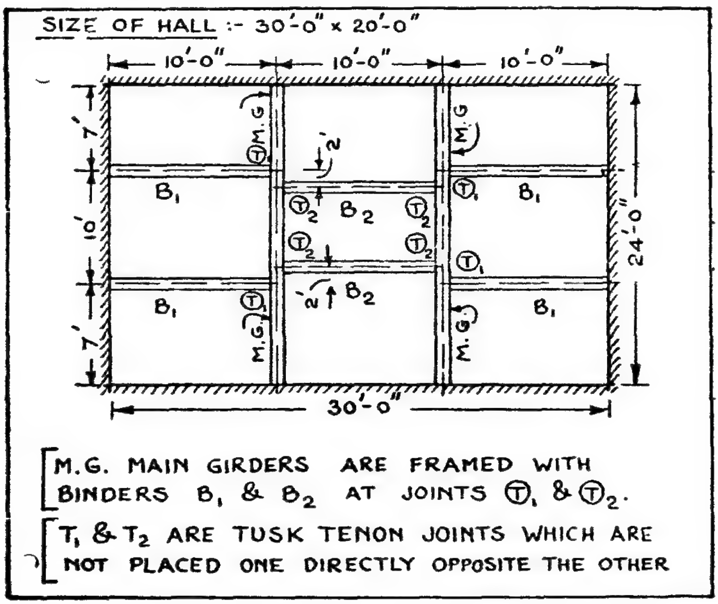


Fig. 351. Framed floors. Showing the method of fixing binders to girders.

(i) *Loods and Bending Moment*—

LOADS

Live load	80 lbs./sq. ft.
Dead load (due to self load of members, flooring and ceiling) ...	40 lbs./sq. ft.
Total load =	120 lbs./sq. ft.

It is further assumed that the loads due to the binders

act at $\frac{1}{3}$rd points on the girder. Thus we have total load at each $\frac{1}{3}$rd point due to both the binders resting on the girder, given by,

Load, $W_1 = 8 \times 10 \times 120 = 9600$ lbs.

Bending moment in the middle-third length of the girder equals.

$B.\ M._1 = 9600 \times 8 \times 12 = 9{,}22{,}000$ in. lbs.

The bending moment $B.\ N._2$ due to self load of the girder may be calculated by assuming a girdes section of 12" × 18". and be included in the value of $B.\ M.$

$$\therefore B.\ M._2 = \left\{ \frac{12 \times 18}{144} \times 56 \right\} \times 24 \times \frac{12}{8}$$
$$= 84 \times 24 \times 24 \times 1.5 = 72{,}300 \text{ in, lbs.}$$

∴ Total value of bending moment for which the girder has to be designed, is equal to,

$B.\ M. = 9{,}22{,}000 + 72{,}300.$
$= 9{,}94{,}300$ in lbs.

(ii) *Design of Girder Section*—Using a specially selected timber ane allowing a working stress of 1350 lbs./sq. in. we have,

$$Z = \frac{9{,}94{,}300}{1350} = 737 \text{ in.}^3$$

Or $bd^2 = 737 \times 6 = 4422$ in^3

Adopting a width of $b = 13$ ins. the required depth for the girder equals, $d = 18.5$ ins.

∴ Adopted size of girder is 13" × 18½".

(iii) *Check for Defection*—Deflection at centre of span is given by, —

$$d_1 = 2 \times \frac{9600 \times 24^3 \times 12^3}{56 \times 1.5 \times 10^6 \times \frac{1}{12} \times 13 \times 18.5^3} = 2\ \frac{W_1\ l^3}{56\ \text{E}\ \text{I}}$$
$$= 2 \times 0.4 = 0.8 \text{ inch.}$$

Deflection due to self load of the girder,

$$d^2 = \frac{5}{384} \cdot \frac{84 \times 24 \times 24^3}{1{,}5 \times 10^6 \times \frac{1}{12} \times 13 \times 8.5^3} = 0.06 \text{ inch.}$$

∴ Total deflection,

$$d = 0.80 + 0.06 = 0.86 \text{ inch.}$$
$$= \frac{0.86}{24 \times 12} = \frac{1}{300} \text{ of span.}$$

(iv) *Shear Stress*—Total shear force at the supports equals,

$$S = 9600 + 84 \times 12$$
$$S = 9600 + 1008 = 10608 \text{ lbs.}$$
$$\text{Shear stress } S = \frac{3}{2} \times \frac{10608}{13 \times 18.5}$$
$$= 66.2 \text{ lbs/sq. in.}$$

(v) *Bed Blocks*—Girders also require bed blocks for them to rest on the wall for distributing the load carried by them. In the present case, load on the wall at each end of the girder is,

$$S = 10608 \text{ lbs.} = 4.75 \text{ tons.}$$

Adopting 2′ - 6'' + 1' - 0'' + 0' - 6'' as the size of bed blocks, as shown in the figure, the stress in the wall equals,

$$\text{stress} = \frac{4.75}{2.5} = 1.9 \text{ tons/sq. ft.}$$

(vi) *Binders and Bridging Joists*—It will be seen that the binder size suitable in this case is 7″ × 10″.

Similarly, the size to the joists, @ 14″ c/c. fou 10'–0″ and 9'–0″ spans is 2″ × 7″; and for 7'–0″ and 6'-0″ spans, the size is 2″ × 5″.

Note—It will be seen from the above calculations that when the span is great, the required sections for the girders become too large for practical purposes. The girders thus become too bulky and uneconomical. Consequently sections for bigger spans are designed either of steel or reinforced concrete or sometimes of built-up section of wood and steel. The method of providing ceiling is given later,

Art. 137. Openings in Timber Floors—*Trimmers and Trimming*—Openings in floors are required either for a stair, hearth or a lift well. As openings are weak points in a floor-special methods of construction have to be adopted. Trim,

mers and trimming joists are used around the openings and a complete frame work is made to secure strength and rigidity. Along the opening, the normal bridging joists are trimmed and are connected by a cross beam called a '*Trimmer.*

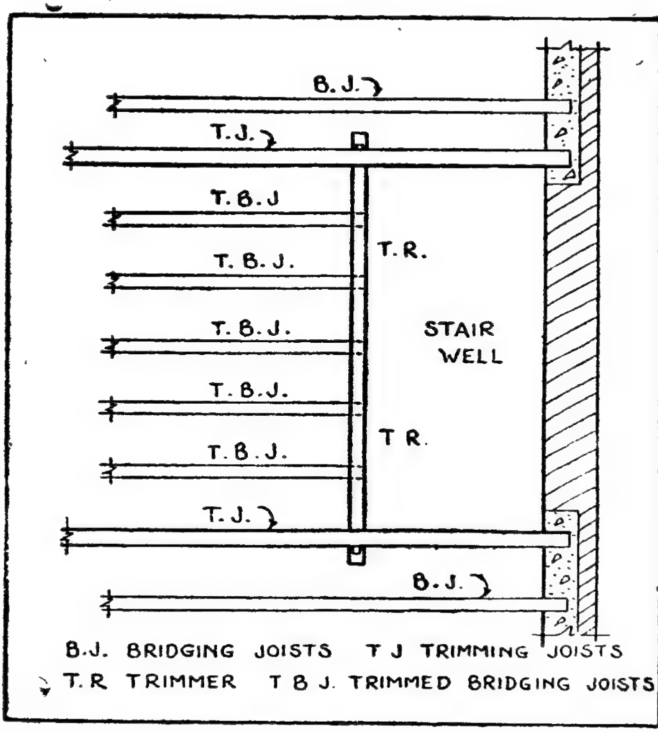


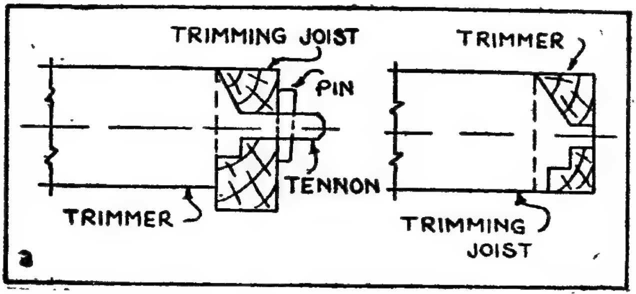
Fig. 252. Frame-work arround a stair well.

trimmer is secured at its ends by *tusk and tenon* joint to the bridging joists and tightened with the aid of a pin driven in the projected tenon. See Fig. 352 where the general frame work around a stair well is shown. In Fig. 353 and 354 are shown the details of the two types of joints required for this frame-work.

The bridging joists to which the trimmer is secured are made slightly of a section thicker than the other bridging joists as they have to be stronger for carrying the

trimmer. The trimmed joists are also framed into the timmer by means of tusk and tenon joint, except that the tenon does not project out to carry a pin, as already described above.

As an alternative method of fixing trimmed bridging joists to the trimmer, dovetailed housing is employed. See Fig. 255



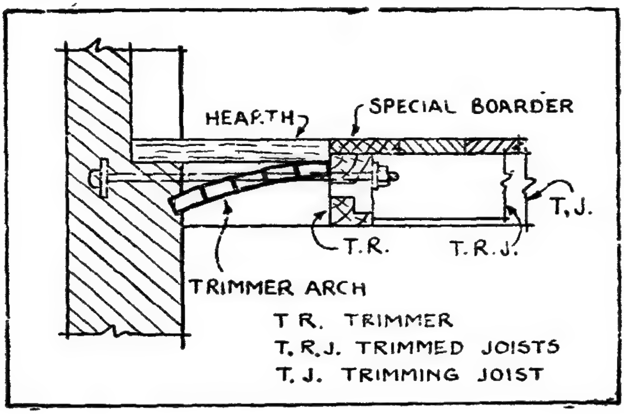
Figs. 353. Tusk tenon joint with pin.
Fig. 354. Tusk tenon joint between trimmed bridging joist and trimmer.

on page 145 under joinery. The trimmer carries the housing into which is inserted from top the dovetailed projection cut at the edge of the trimmed joist. One side of the projection is dovetailed while the other is kept square.

In all the above cases, during construction the trimming joists are laid in position with the trimmer placed across, and then the trimmed joists are finally inserted in position. When this is complete, the wedges are driven in position in the two tenons of the trimmer, to tighten the frame work of the opening.

Fireplace Openings–The trimming required for providing openings for the place is shown in Fig, 355. A trimmer arch is turned from the wall to the trimmer to support the hearth. If the arch is a complete one, a tie rod should be used to tie the trimmer with the wall. The tie rod is properly secured in the wall by means of a steel plate of about one foot square. Steel tie rods of about $\frac{5}{8}''$ diam. placed at a spacing of 12" to 15" are usually found sufficient.

Art. 138. Flooring and Floor Boards—The flooring over the bridging joists consists of floor boards laid continuously side by side in a close fashion. The thickness of the boards varies from $\frac{}{8}''$ to 1 ″, The following are different ways of laying and jointing boards.



Fld. 554, Trimming for fire place.

(i) *Fig. 362 Plain Jointed; Straight or Square Jointed*- The boards are laid with their joints straight or plain, and fitted in as close as possible. Nails are driven through the boards to fix them to the joists.

(ii) *Rebated*—Figs. 356 and 357 to overcome the defect of opening of the joints through the entire depth of boarding by shrinkage, many devices are used. In one case the sides of the boards are rebated longitudinally to from a lapping joint.

(iii) *Tongued, and Grooved*—Figs. 358 and 359. One side of the board is grooved and the other side has a tongue which fits in the groove of the adjacent board.

(iv) *Rebated, Tongued and Grooved*—This is a combination of tongued and grooved joint and rebated joint, as shown in Figs- 360 and 361. This jointing admits of secret nailing on the tongue for fixing it to the joist below, and thus gives a neat and clean appearance to the floor.

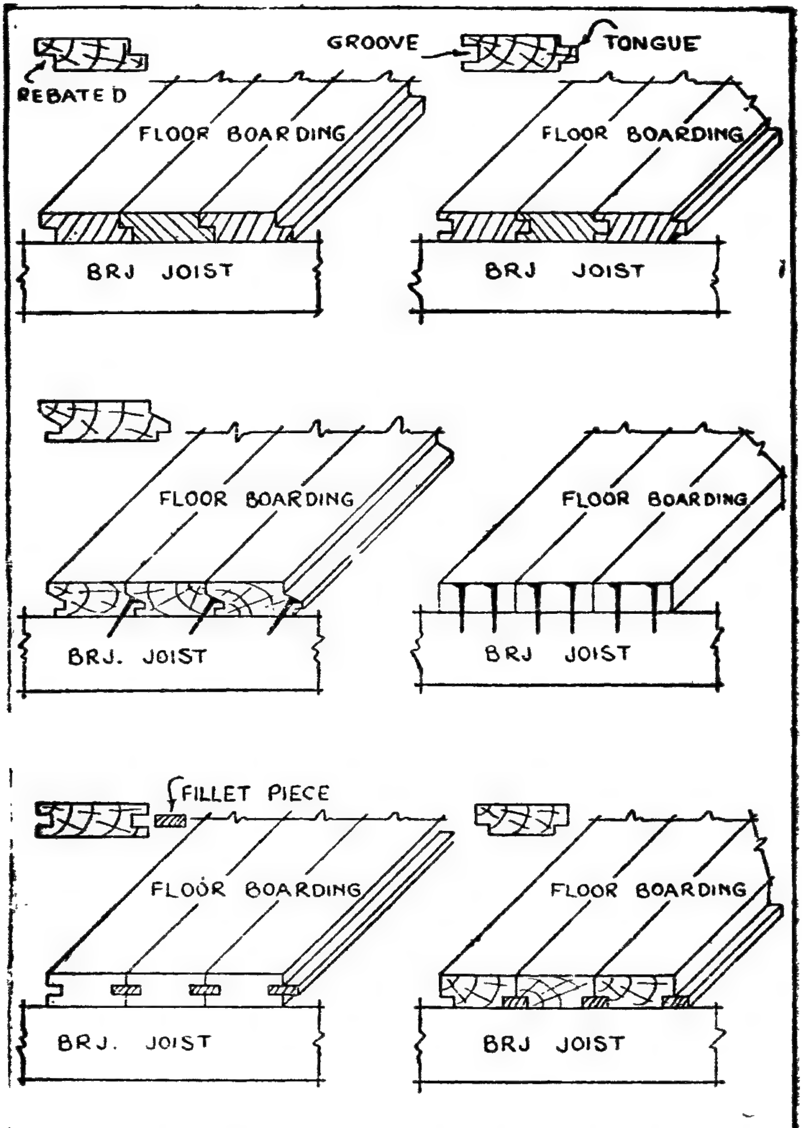
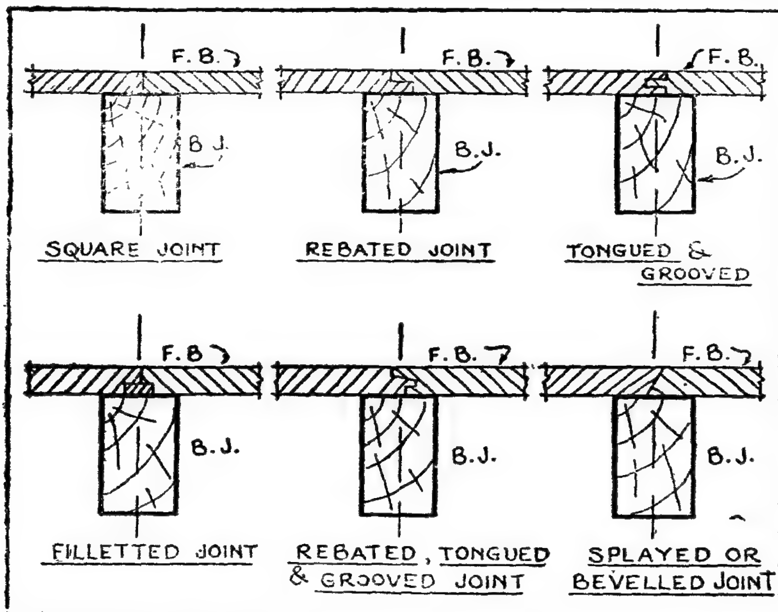


Fig.s 355 and 257. Rebated joint. Figs. 358 and 359. Tongued and grooved joints. Figs. 360 and 361. Rebated, tongued and grooved. Fig, 362 Simple butt joint. Figs. 363 and 364. Ploughed and tongued joint 366 and 366. Rebated and filleted Joint.

(v) *Grooved Joints*, shown in Figs. 363 and 364, with independent tongues are also sometimes adopted. The tongues are commonly of hoop iron. These joints are essentially straight or plain, but narrow grooves are cut in the sides of each boarding into which are inserted hoop iron tongues.

(vi) *Rebated and Filleted*—In this case the boards are rebated on their lower face on both sides and a fillet piece is laid to cover the joint in the rebated portion. See Figs. 365 and 366.

Sometimes plain or straight joints are improved in their strength with the aid of dowel pins of iron driven on the sides.



Figs. 337 to 372. Heading joints for floor boarding.

Art. 139 Heading Joints—Usually the flooring boards are not of sufficient length to cover the whole length or width of rooms in one piece. They have therefore to be jointed at their ends. These joints are termed as heading joints and are

essentially the same as those mentioned above, and could be easily understood from the sketches given in Figs. 367 to 372. All heading joints should be formed on joists. It is neceessary to break these joints on alternate joists so that two adjacent joints could not come on the same joist.

The thickness of the boarding is uniform throughout the floor and varies from $\frac{7}{8}$ in, to $1\frac{1}{2}$ in, for any floor as already mentioned. The floor boards can be of any width from 4'' to 8'' but a width of 6 ins. is very convenient to obtain and to use also. It is a usual practice to use planks of the same width throghout each floor to have straight longitudinal joints and also for appearance and convenience of construction.

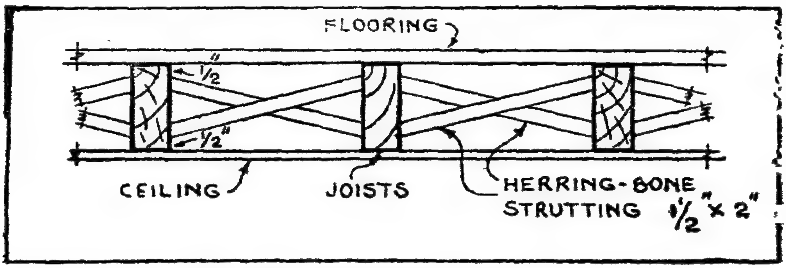


Fig. 373. Herring-bone strutting.

In special floors with much wear and tear, two layers of floor boards are used, one laid directly over the other. The lower one may be of $\frac{3}{4}$ thickness and the upper wearing surface of 1" to $1\frac{1}{4}$" thickness. It is a sound method of construction, when two layers of flooring boards are used, to lay the lower layer diagonally on the joists and the top layer normally and at right angles to the joists.

Art. 140. Strutting of Joists—Joists laid across greater spans are usually deeper in section as compared to their width. Such deep narrow joists are liable to side buckling and side tilting. To prevent this they require to be strutted at intervals of 5 to 6 feet. This offers the necessary stiffness and rigidity to the floor as a whole and helps the flooring boards to distribute the load effectively over the joists.

Upto spans of 13 feet one row of struts is enough; but for longer spans two rows of struts have to be provided.

The following are the two methods of providing lateral strutting to the joists,—

(i) *Herring-bone Strutting*—This consists in providing a system of cross bracing of two diagonal 2" × 1½" size, in each bay, as shown in the figure. It is preferable that the diagonal pieces should have their ends splayed and fixed to the joists leaving ½ in. clear at their top and bottom. This prevents them strutting against the floor boards and ceiling planks. See Fig. 373. The struts are fixed to the joints by means of nails 2" to 3" long,

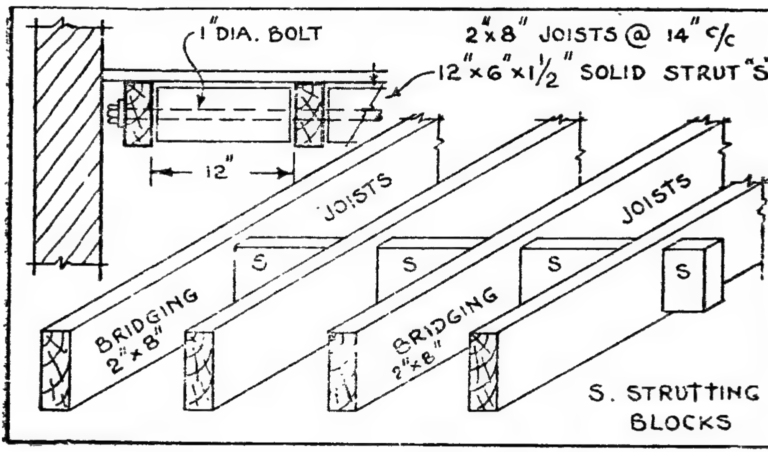


Fig. 374. Solid strutting of floor joists,
Fig. 376, Solid strutting: Isometric view.

(ii) *Solid Strutting or Stemming.* A simple method of providing lateral strutting is to insert short pieces of timber 2" to 3" wide and 1" to 1½" thick between the joists in a row, and to tighten firmly with the aid of a 1" diam. bolt as shown in Fig. 374 and 375. The bolt passes continuously through the joists also. This method is not as sound in action as the previous one since the strutting pieces tend to become loose by shrinkage in the course of time.

Atr. 141. Floor Ceilings—Ceilings are provided to floors to improve their appearance from below and to prevent the passage of sound and smell between the rooms. The ceiling can be either of planks or of lath and plaster or of special plaster boards.

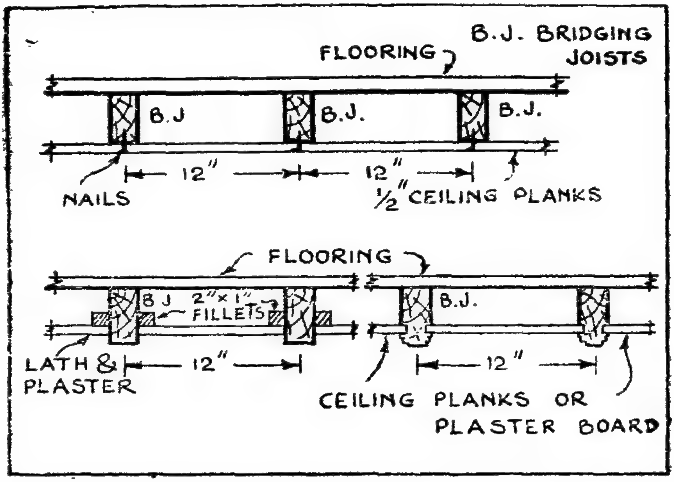


Fig. 376. Closed ceiling.
Figs. 377 and 378. Open ceiling with fillet pieces and with grooves

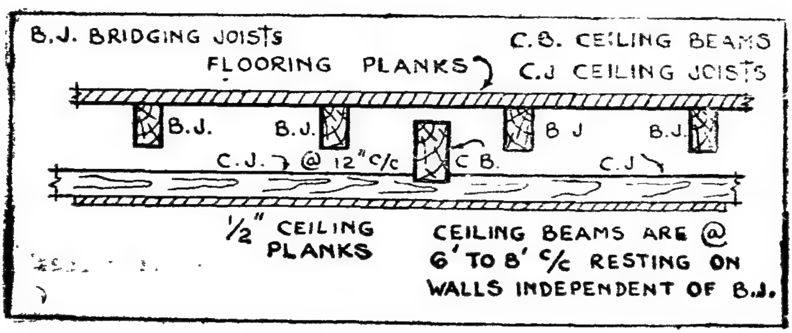


Fig. 379. Independent floor ceiling.

(i) *Closed Ceiling*—Ceiling planks are fixed directly to the underside of the briding joists. Though this method is a simple one, it has the defect of causing the ceiling

planks to crack as the floor vibrates and deflects under moving loads. Fig. 376.

(ii) *Open Ceiling*—In open ceiling, the flooring joists appear from below. 2" × 1" fillet pieces are nailed on the

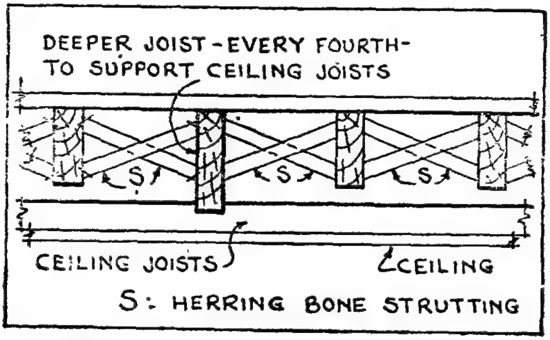


Fig. 380 Ceilings for single floors.

sides of the bridging joists to fix lath from below. Lath is then plastered over as shown in Fig. 377.

If ceiling planks or plaster boards are to be used for providing open ceilings, grooves are chased in the sides of

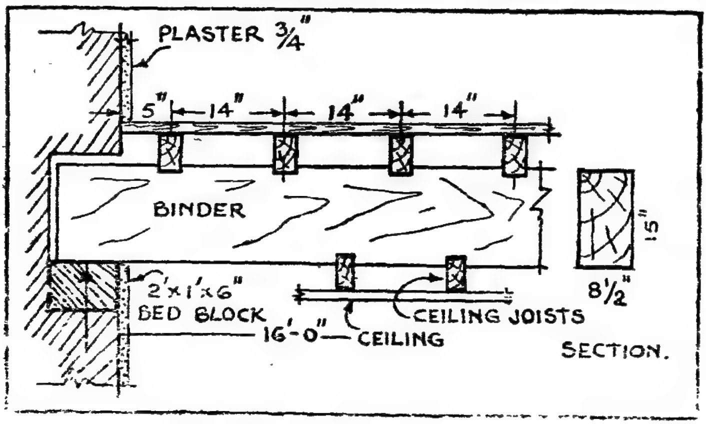


Fig- 381. Ceilings for double floor.

the bridging joists and planks are inserted inserted in them shown in Fig. 378. Usually some type of moulding is done at the under side of the joists in the clearance between their lower face and the ceiling planks.

Art. 142. Ceiling Joists—It is always a better method of construction to make the ceiling independent of the members which support the main floor. Ceiling joists are provided to support the ceiling independently. In a single floor, ceiling joists are fixed to ceiling beams and run at right angles to the bridging joists as shown in Fig. 379. Ceiling is then fixed to their under-side. It may be of planks or of

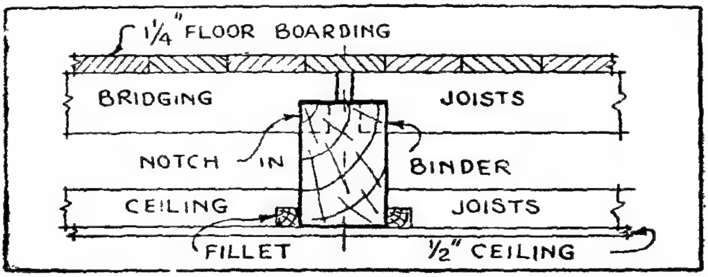


Fig. 382. Ceilings for double floor.

lath and plaster as required. Sometimes, instead of separate ceiling beams, bridging joists at interval of 5 to 6 feet are of a deeper section to support the ceiling joists. This method is illustrated in Fig. 380 where herring bone strutting is also shown.

When a ceiling is provided for a double floor, bridging joists and ceiling joists are both connected to the same binder as shown in Figs. 381 and 382. In such a case, the following points should be noted :—

(*a*) The bridging and the ceiling joists may be fixed with the aid of parallel fillet pieces driven along the sides of the binder. This is the best method as no part of the binders or joist is weakened by notching.

(*b*) Either the bridging joists or the ceiling joists are fixed by cutting notches in the binders, and the other by employing the fillet pieces.

(*c*) The bridging joists and the ceiling joists may be fixed to the binders by cutting notches in each case. Though

this is a simple method, it weakens the binder at top and bottom by a number of notches cut in it and therefore should be avoided as far as possible. The total thickness of the floor is also increased.

Art. 143. Ground Floors of Timber—Sometimes ground floors are constructed of timber as in the case of carpentry halls, ball rooms, dance halls, and for rooms of buildings in cold countries. Sleeper walls are built above the ground to support the bridging joists as illustrated in Fig. 383. Sleeper walls are dwarf walls built with their top just below the floor level and are intended to reduce the span for the joists. They carry wall plates to allow the bridging joists to be fixed on them. In the construction of these floors proper precautions should be taken to prevent the rise of damp into the building. Usually a damp-proof

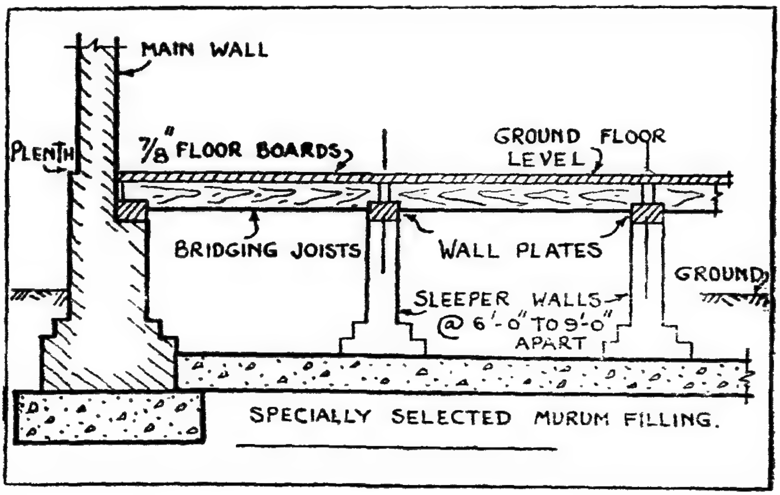


Fig. 383. Ground floor of timber.

course just below the wall plate solves the problem. On top of the bridging joists floor boards are provided as in the case of other floors described before.

Art. 144. Pugging and Sound Proofing—The usual objection to timber floors, apart from their susceptibility to catch fire, is the penetration of sound through them. Several methops are adopted for preventing the passage of sound from one room to the other through timber floors. One of the methods is to provide pugging which consists in filling a plaster (coarse stuff).—a mixture of mortar and chopped straw—on the special supports provided for the puropose at a lower level by the side of the floor joists. On each side of the floor joists $1\frac{1}{2}'' \times \frac{1}{2}''$ fillets are nailed for supporting the sound boarding to carry the pugging as in Fig. 384. The fillets are sometimes replaced by $1'' \times 1''$ angle irons screwed on to the sides of joists. The pugging material may also be held in position by suspending it in felt hung from joists.

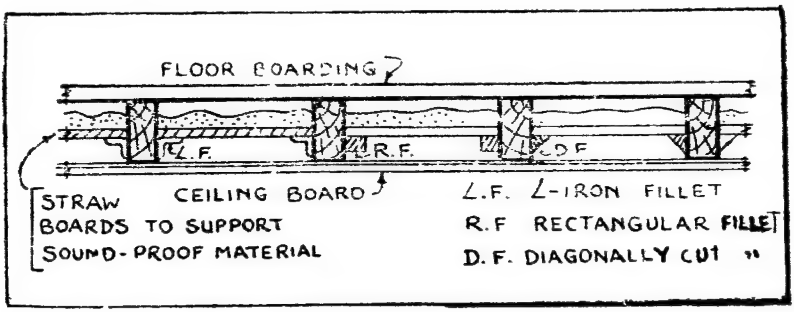


Fig. 384. Sound-Proofing of timber floors.

Since the idea in providing pugging is fo absorb and deaden the souud, materials like saw-dust, asbestos and silicate cotton are also used instead of pugging plaster. In fact the method of pugging is becoming old-fashioned, as different types of plaster boards and acoustic preparations are now available. Moreover pugging prevents the access of air to the interior of flooring and hence it is liable to et up rot and decay in timber. The formation of hollow spaces in floors could be prevented by using a solid filling of slag wool.

CHAPTER XII

Stairs and Stair-Cases

Purpose and location of stairs. Materials of stairs. Terms used. Steps. Strings. Hand rails. Head room. Different forms of stairs. Requirements of riser and tread relations.

Design of teak-wood stairs. Illustrative problems. Metal stairs. Reinforced concrete stairs. Illustrative problem, Composite stairs. Stone steps and stairs.

Art. 145. Purpose and Location—Stairs are provided in buildings to facilitate the ascent or descent from one floor to another. They consist of a set of steps so designed that this ascent and descent may be made with ease, comfort, quickness and safety. A flight is formed by a series of steps, and between two floors there may be two or more flights. Between two flights of steps, horizontal platforms called landings, are provided.

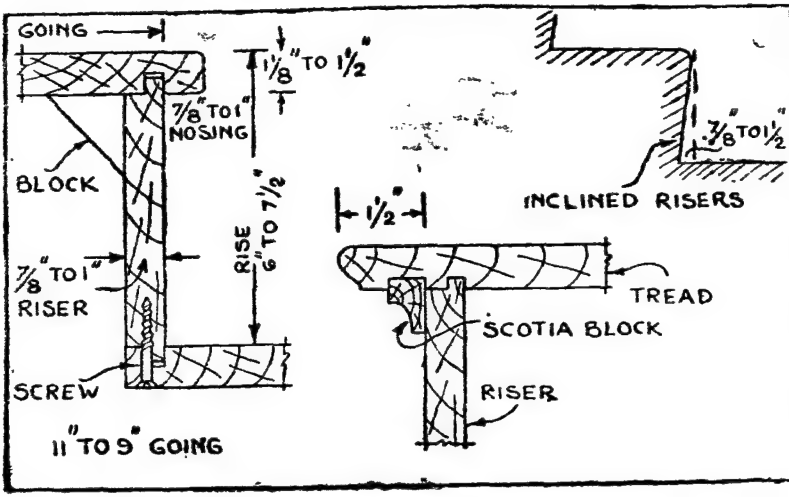
Stairs are placed in a building either in a space which is a part of a big hall, or in a separate room. The enclosure provided for locating the stair is called a staircase. The position to be allotted to a staircase in a residential building or in a public building requires a careful consideration depending upon the purpose of use in each case.

A stair essentially consists of a horizontal portion called a "*tread*", connected to a vertical portion called a "*riser*". both of them constituting a "*step*". The ends of steps are connected to stout inclined planks called "*strings*" and the steps rest on them.

It is often desirable, for provision of both light and ventilation, to have one wall of staircase, an external wall. The lighting of a staircase, needs special consideration at all turnings and landings. Semetimes top lighting may be arranged in open-well stairs.

Art. 146. Materials of Stairs—Depending upon their cost, durability and asthetical importance, stairs are built up

of various materials such as, wood, stone, bricks, steel, wrought iron or reinforced concrete. Sometimes two of more of the above materials are used in the same stair. The selection of materials for a stair-case also depends upon



Figs. 385 and 387. showing details of treads and risers with the methods of fixing them to each other. Fig. 386. Inclined risers.

the fire-resisting qualities expected of it. Occasionally treads, risers and soffits of a stair are finished with special materials such as marble, patent stone,--plane, mosaic or checkered, lath and plaster, etc.

Art. 147. Terms Used—The following are the terms used in the design and construction of stairs :—

Tread is the horizontal member forming the upper surface of a step on which the foot is placed. See Fig. 385.

Treads are usually of the same material as that used for the general construction of the stair. For timber stairs they should be of specially selected hard wood to withstand wear and tear. In public stairs steps are provided with special metal strips at nosing. But occasionally treads of, special materials are fixed to concrete or brick stairs to

improve their appearance and to provide a hard wearing surface. Marble, polished stone, precast clay pieces, or cement tiles are some of the materials used for finishing treads.

For design purpose the width of a tread is measured as the horizontal distance between the faces of two conse-

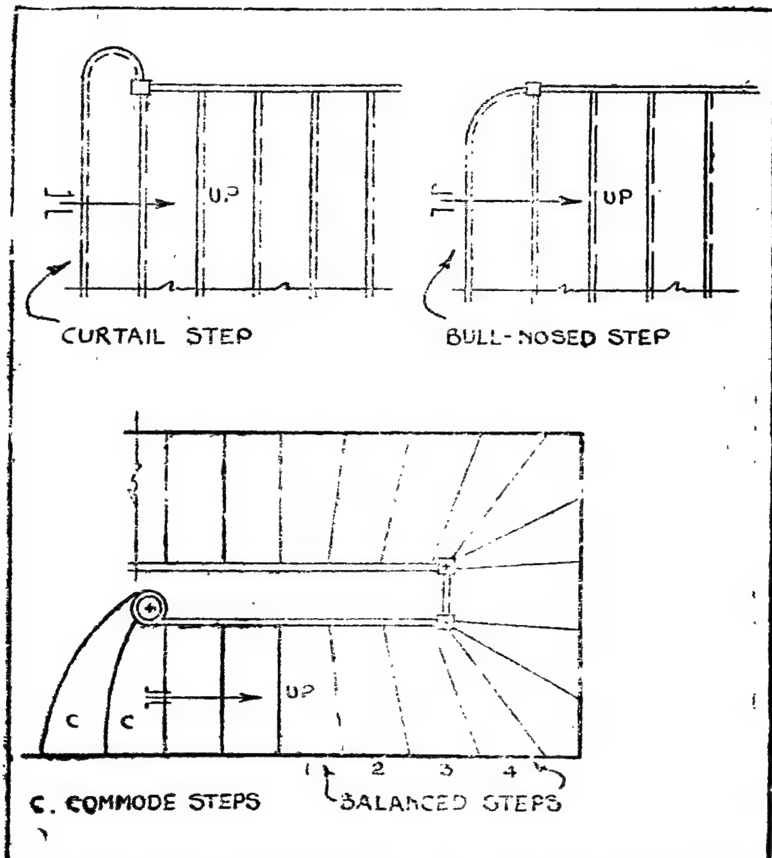


Fig. 388. Curtaits steps. Ffg. 380, Bull nosed step.
Fig. 390. showing commode steps, balanced steps and winders.

cutive risers. But the actual width of the tread available for placing the foot includes the nosing also which is usually provided.

Riser is the verical front member of a step, and connects the front of the upper tread with the back of the lower. Its use is measured as the vertical distance between the tops of two consecutive treads. The total rise of a flight is the height between two floors or landing to landing, as the case may be. See Fig. 385.

Nosing is the projecting front edge of a tread. It is the distance between the front edge of the tread and the face of the riser immediatly below it. The projection of the nosing is from $\frac{3}{8}''$ to $1\frac{1}{2}''$. See Fig. 387. Sometimes the nosing is proyided by giving an inward slope to the riser. See inclined risers in Fig. 386.

Line of Nosing is a line drawn touching the projecting edges or nosings of the treads of a flight.

Scotia Block—In addition to ordinary rounding of nosings, specially moulded scotia blocks are provided, mainly for apperance. But scotia blocks also add to the strength of the tread at nosing, when the latter has a longer projection. A small groove is cut at the underside of the nosing in which the scotia block fits in. See Fig. 387.

Art. 148. steps—A step consists of a tread and a riser. A step of uniform width and rectangular in plan is termed a "*flier.*"

A Curtail or Scroll Step is the lowest step of a flight with its one or both ends finished semi-circular or spiral in plan. See Fig. 388. When a curtail step has its end half round, in plain, it is called a " Bull nosed step. " See Fig. 389.

Commode Steps have a curved riser and tread. Their vertical face is convex on the plan. The lowest few steps of stair are sometimes commode steps. See Fig. 390.

Winder Steps are used where the direction of a flight is changed. They are traingular in plan and radiate from a point, which is usually the centre of a newel post. Unless the space for a staircase is limited, the use of winners in a

main stair should be avoided owing to inconvenience of use. The central of these winders, shown in Fig. 390 is called a kite winder, on account os its shape. Along the *walking line* or the *line of travel*, see Fig. 415, the width of a winder should not be less than the normal width of a tred. Sometimes diminished fliers with their one of the edges. narrrowed down are used between the fliers and the winders, and are called *danciug or balancing steps*. These are shown marked 1, 2, 3, and 4 in Fig. 360. A balanced step does not radiate from a common centre and has a normal width along the line of travel and is therefore more safe to use.

Going or Run of a step is the horizontal distance between the faccs of two consecutive risers. See Fig. 301. It is exclusive of the nosing which forms an additional projection to each step. The going of a flight is the total horizontal distance between the face of the bottom riser and that of the top riser measured along the travelling line.

Art. 149. Strings (also called *Stringers*)—These are the inclined members for supporting the steps. For each flight there are usually two strings, one on each side.

(*a*) There are two principal methods adopted for fixing the ends of treads and risers to the strings. Accordingly strings are classified into two main types, as follows:—

(i) Closed or Housed Strings.

(ii) Cut, Open or Notched Strings.

The following are the constuctional features of these two types of strings.

(i) *Closed or Housed String*, has top and bottom edges parallel and on its inner face grooves are cut to a depth of $\frac{1}{2}''$ to $\frac{1}{4}''$ as shown in Fig. 391 to receive the ends of treads and risers. The sides of these grooves on the upper and on the front side are kept true to the correct shape of treads and rises, while the sides of the grooves towards the lower edge of the string are splayed out to form a wedge. shape. The treads and risers are housed into ihe grooves and wedges

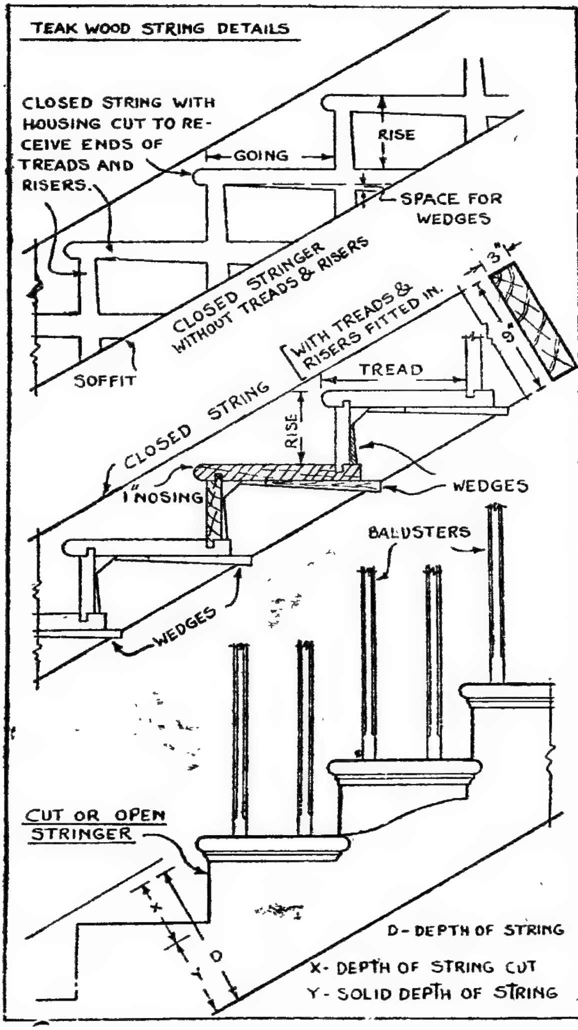


Fig. 391. to 393. Details of teak wood stairs.

are driven to fix them up finally. See Fig. 392. To give rigidity at the joint, 3" triangular blocks, 3 or 4 per step are fitted from the inside connecting the tread and the riser.

The two strings of each flight, together with the correspoding number of steps, are held in position by three or more iron bolts with washers, each passing through from one string to the other.

The string which is placed against a wall is called a wall string and the one on the outside is known as outer string.

In the case of reinforced concrete stairs, if strings are provided, they are cast monolithic with the steps as explained later.

(ii) *Cut, Open, or Notched String* has its top notched as snown in Fig. 393, and the ends of treads and risers rest on the horizontal and vertical parts of the notch respectively. If the tread projeets beyond the outer face of the string so that the same projection of the nosing is turned on this side also, it forms a returned nosing. The lower edge of the cut string is kept parallel to the line of nosing, which touches the projecting edges of treads.

(b) Carriers–If stairs are very wide, one or more strings are provided at intermediate positions in addition to the end ones. These are called *rouh strings or carriers.* Their tops are either notched to receive the treads and risers, or additional rough brackets are fitted, one under each step.

(c) Soffit is the under surface of a stair and is usually neatly finished with a ceiling of planks or plaster.

(d) Spandril—The underside triangular space between the outer string and the floor, is often covered with a wall or planking and is termed af *spandril.*

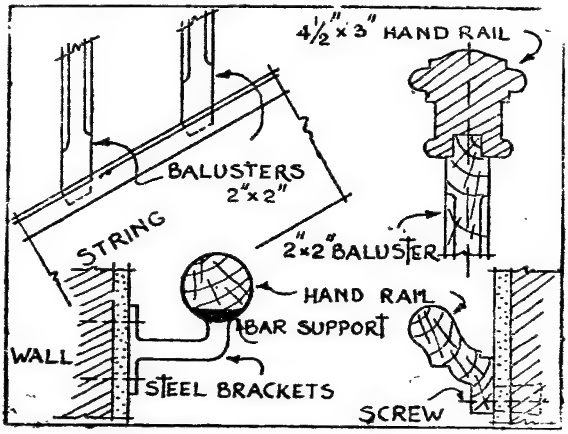
Art. 150. Hand Rail, Newel Post, and Landing—

(i) *Hand-Rail*-is a special rail, usually rounded or moulded, fixed above and parallel to the string at a convenient height. It is intended to afford: assistance and safe-guard to persons while going over a staircase. Its size and shape should enable an easy grip by the hand. See Fig. 395. Usually a hand rail runs between two newel posts and is supported

by balusters. See Fig, 394. On the wall side hand rails are convenently fixed to brackets as shown in Figs. 396 and 397. It may be noted that wooden hand-rails are very convenient and pleasanient to use.

(ii) *Newels or Newel Posts* are vertical members square, moulded or turned, placed at the ends of flights to connect hand rails and strings into a frame work.

(iii) *Balusters and Balustrades*—Balusters are short vertical members fixed between the hand rail and the string,



Figs. 394 to 397, Details of hand rails and methods of fixing.

intended to support the former, and also to protect the open space by the side of a flight. The complete frame work comprising balusters, hand rail, newel posts and the supporting strings is called an open balustrade. If the open space is covered up by panelling instead of balusters, it is rermed as solid balustrade.

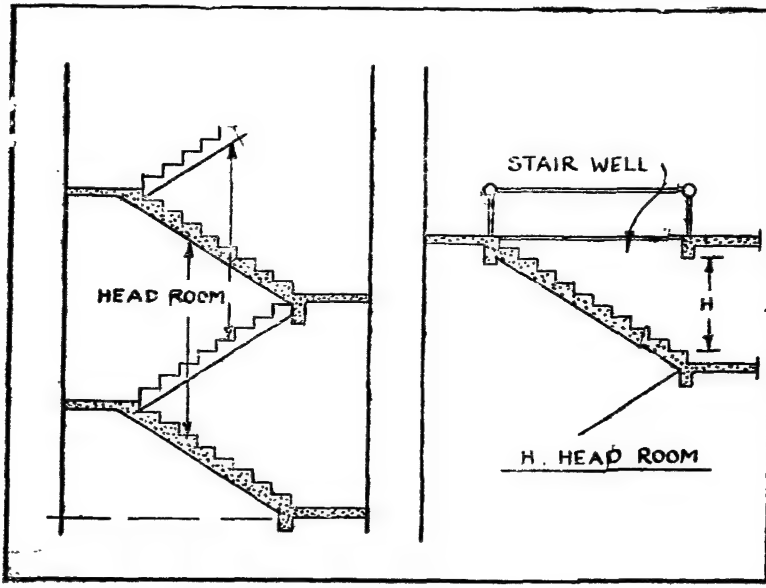
(iv) *Landing* is a platform between two flights to afford provision for turning a stair and to serve as a rest. The width of a landing is not less than the width of a stair.

Art 151. Terms Used *(contd.)* (i)-*Head Room* is the clearance height measured vertically between the line of nosing and the soffit or landing of the flight immediately

above it. The head-room over stairs should not be less than 7′-0″. See Figs. 398 and 399

(ii) *Pitch or Slope* of a flight is the general inclination of the line of nosing to the floor or landing.

(iii) *Walking Line*—A person ascending or descending a stair normally travels along a line whieh is usually 1–6″



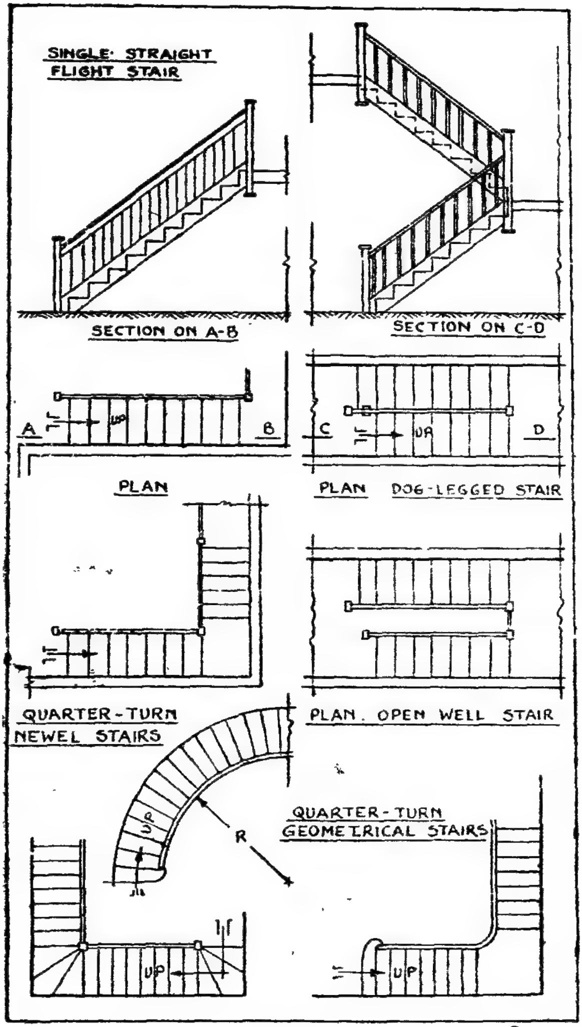
Figs, 398 and 309. Showing xead-rcom in a staircase,

from the centre of the hand rail. This line of travel is known as the walking line. See Fig. 415.

(iv) *Storey Rod* is a specially prepared piece of wood for marking accurately the number of steps between any two floors. A storey rodis approximately 3″ × 1½″ scantling sufficiently long to extend from floor to floor.

(v) *Stair-case* is the enclosed area provided for locating the stairs in a building, the floors of which are served by the respective stairs.

Art. 152. Different Forms of Stairs—



Figs 400 to 408. Different types of stairs.

Stairs are classified as follows:—

(i) Straight flight stairs,

(ii) Turning stairs.

(iii) Circular stairs.

The following is a description regarding these varieties of stairs.

(i) *Straight Flight Stair*, is one in which all the steps lead in one direction. It may consist of a single flight, or two or more flights in a length, each separated by a landing. See Figs, 400 and 401.

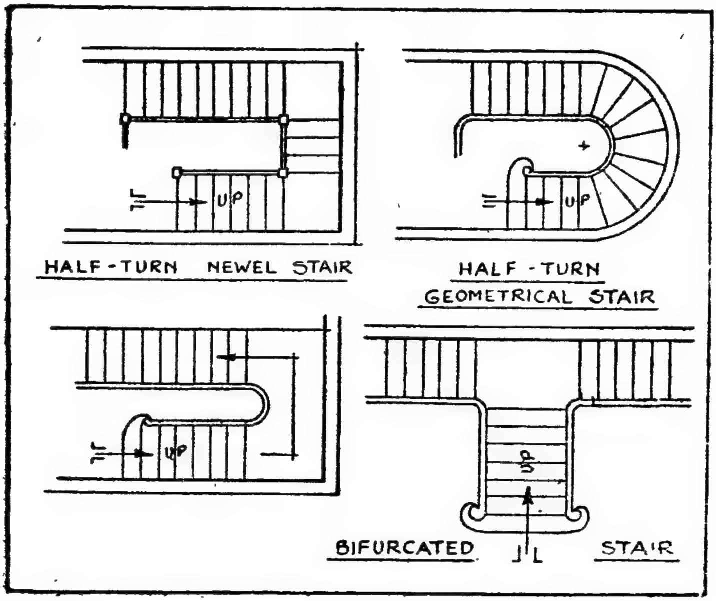


Fig. 409. Newel stair.
Figs. 410 and 411. Geometrical or continuous stairs.
Fig. 413. Bifurcated stair.

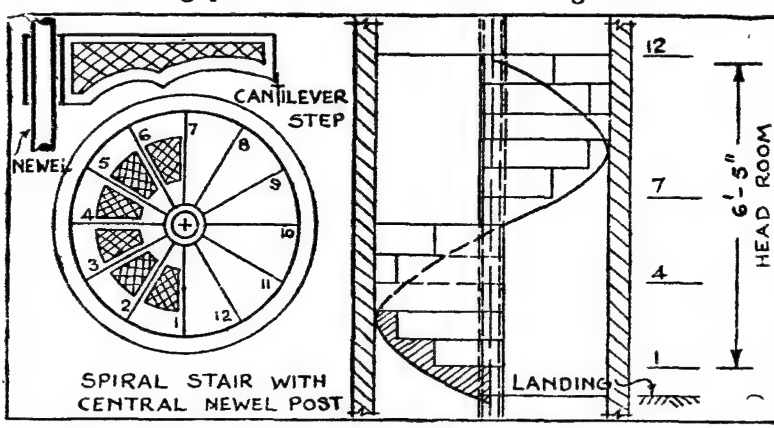
(ii) *Turning Stairs*—These staris include the following varieties,—

(a) *Quarter-turn Stairs*—See Figs. 402 to 403. When the direction of the flight is changed at right angles either to the left or to the right, quarter turn stairs are used. At the turn, quarter-space landings or winders are used.

(b) *Half-turn Stairs*—In these stairs, the consecutive fights are in the opposite directions and are separated by a half-space landing as in the case of dog-legged stairs, or a

quarter-space landing and winders, or two quarter-space landings and a flight (usually a short one), or by winders alone. See Figs. 406 to 408.

(c) *Bifurcated Stair*—This has the bottom flight divided at the landing into two narrower flights, one to the right and the other to the left. The bottom flight is wider than the top two flights. Sometimes a bifurcated stair is formed by having one common flight while descending upto the landing and dividing itself into two narrower flights for the remaining part of the descent. See Fig. 412.



Figs. 413 and 414, Spiral stair with a central newel post.

(d) *Open Newel Stair*—When space is available and it is intended to locate a lift in the middle of staircase room, a rectangular well hole or opening with a distinct corner at every change of direction is provided. The respective flights are arranged arround this open well. At the head and foot of each flight of stair are placed newels which form a conspecuous feature for the stair to be called as "*newel stair*". The stair well also gives facilities for lighting from top. In public buildings stairs are usually designed as open well type. See Fig. 409.

(e) *Geometrical or Continuous Stair*—The strings and the handrails are continuous and curves are introduced between the flights to eliminate sharp corners. This enables

the winders introduced at change of direction, to be wider and hence more convenient to use than those in a newel stair. Geometrical stairs can be circular, elliptical, or of any suitable curve. See Fig. 407.

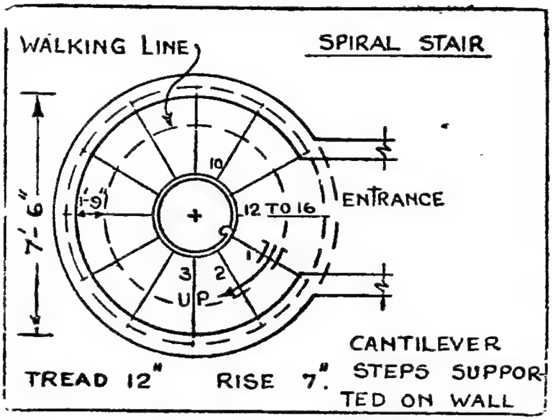


Fig. 415. Spiral stair with a central circular well-hole.

(ii) *Circulars Stairs* are biult up of steps which are all winders arranged either around a central newel post, see Figs. 413 and 414. or arranged as canti-levers from the supporting wall with a circular well-hole in the middle as shown in Fig. 415. Circular stairs are built of R. C. C, stone, or iron and are enclosed in a circular stair-case. When all these steps radiate from a central newel post, they form a *Spiral Stair*. Iron spiral stairs are very common and are specially used for service purposes. They are not usually enclosed in a stair-case.

While designing a circular stair, the width of tread along the walking line which is at a distance of 1'–9" from the outer circle of the stair, and the provision of an adequate head requires proper consideration.

Art. 153. Requirement of a Stair—The following are the essential requirments of a well-designed stair which can be used with ease, comfort and safety.

(1) It should be located in buildings in a position where there is both light and ventilation, specially at all turnings.

It should be in a position that it can be conveniently approached.

(2) The width af a stair must be adequate to serve the needs for which it is intended. An average value of 3–'0" is usually taken for the width of a stair in a domastic building and 4'–6" in a public building.

(3) It should not be too flat or too steep. The proportions of treads and risers should be as given in Art. 154.

(4) Each flight should not contain more than 10 to 12 steps. To facilitate this, adequate number of landings should be provided at intermediate positions. Half–space landings are always recommended. If quarter–space landings have to be adopted, a regular flight of not less than 5 to 6 steps should be introduced between two consecutive quarter space landings.

(5) There must be enough head room in a staircase. Though the minimum head-room required is 6'--6", a greater value should always be aimed at to facilitate the conveyance of furniture and articles. A height of 7'–0" may be adopted as a fair value for the head room.

(6) The recommended values of tread and riser in any particular stair should be uniformly maintained for the whole height to avoid accidents.

(7) Winders should, as far as possible, be avoided in a stair. If they have to be introduced, their design should comply with the requirements given under winders.

(8) Stairs should be provided with properly designed handrails and balustrades on the outer side. The height of an inclined handrail should be 2'–9" and that of a harizontal one should be 3'–1½".

(9) Stairs should preferably be constructed of materials, which possess fire resisting qualities.

Art. 154. Riser and Tread Relations–For convenince of use with ease and comfort, the following ratios are used

between the rise and tread in a stair. This also entails a minimum expenditure of energy.

Rule 1.—The sum of going and twice riser should be between 22 and 24. An 11 inch going will require 6 inch rise. Thus we have the following variations,—

Case (*i*) 11″ + 2 × 6″ = 23 inches.
Case (*ii*) 10″ + 2 × 6½″ = 23 inches.
Case (*iii*) 9″ + 2 × 7″ = 23 inches.

Rule 2. The product of going and rise should be between 64 ins. and 68 ins. Thus in the above three cases, we have,

Case (*i*) 11″ × 6″ = 66 ins.
Case (*ii*) 10″ × 6½″ = 65 ins.
Case (*iii*) 9″ × 7″ = 63 ins.

It may be noted here that the value of "going" in the above rules does not include the nosing of the step as usual; and that stairs with narrower treads, are uncomfortable to use while descending. Treads are seldom made less than 9″ or more than 11½″ wide.

TEAK WOOD STAIR

Art. 155. Dog-legged Stair. Illustrative Problem—The height from floor to floor is usually predetermined and it is necessary to design a stair and to fix up the number of flights and the steps in each flight.

The height from floor to floor of a residential building is 12''—9''. Design the stair to serve the respective floors of this building.

(i) *Tread and riser details—Heigt of riser*—A trial size of 7'' is assumed and two flights are proposed between the two floors.

$$12' - 9'' = 133 \text{ ins.}$$

$$\text{Number of risers} = \frac{133}{7} = 19 \text{ Nos.}$$

As there are two flights, it is desirable that the number of steps in each flight should be equal. Then 18 or 20 steps

are required. If the space is restricted, a smaller number will be found necessary. Otherwise, taking 20 risers, the value of each equals,

$$\text{Riser} = \frac{133}{20} = 6\tfrac{13}{20} \text{ ins.}$$

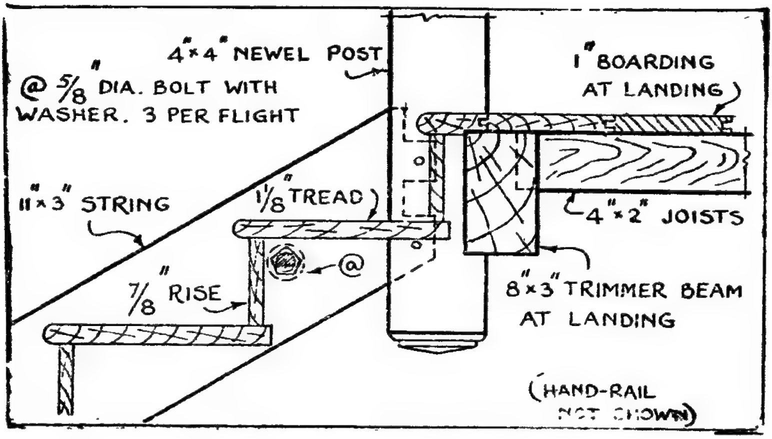


Fig. 416. Showing details of construction at landing.

Such odd fractions are usually met within stair designs and a story rod is prepared, by setting out, to give this rise.

(Alternately if only one stair between ground and first floor has to be designed, then 19 risers of 7" each may be adopted and these can be distributed at 10 and 9 in each flight.)

Width of Tread,—

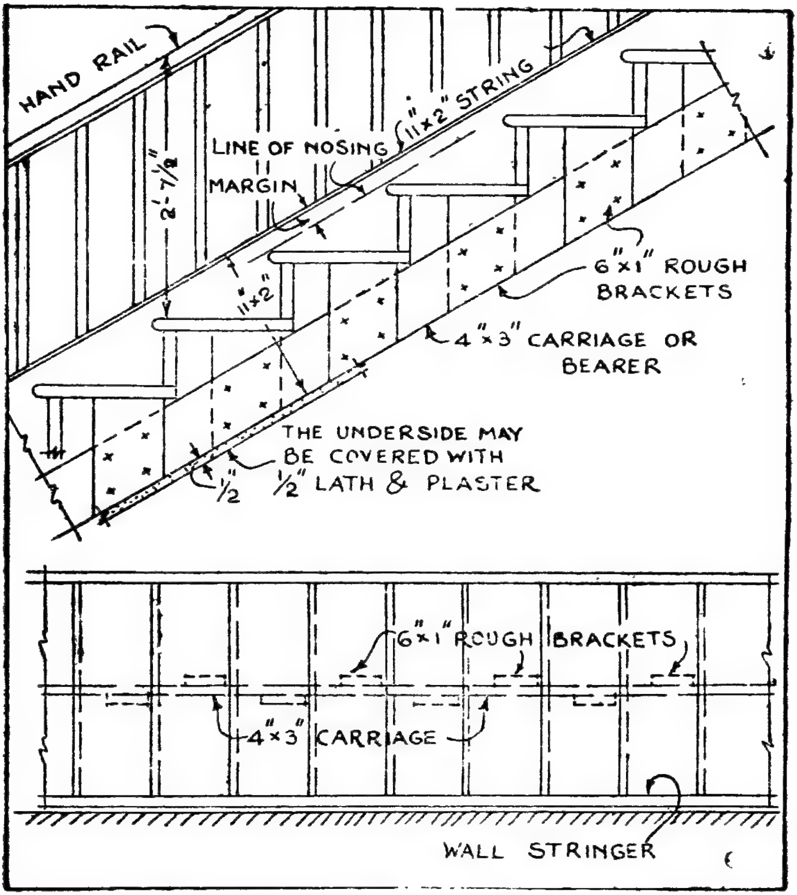
Rule 1. Going $= 23 - 2 \times 6\tfrac{13}{20}$.

$= 23 - 13.3 = 9.7$ ins. **Say $9\tfrac{3}{4}$ inches.**

Providing a nosing of $1\tfrac{1}{4}$ inch, the width of each tread equals 11 inches. But for the purpose of setting out a stair $9\tfrac{3}{4}$ ins. the value of going, is only used.

Rule 2 − $9\tfrac{3}{4} \times 6\tfrac{13}{20} = 64.2$

Art. 156. Illustrative Problem—(*Contd.*) (ii) ***Details of each Flight***—Number of risers = 10. Number of treads = 10 − 1 = 9. The construction details of steps and risers are shown in Figs. 385 and 386.



Figs. 417 and 418. Rough strings or Carriers.

Strings—Housed strings are adopted. The treads and risers are supported on two closed strings, each 10"×3", as shown in Fig. 392. If open or cut strings are used, a size of 12" × 2½" may be adopted for them. The rigidity of the flight as a whole is maintained by means of three 5/8" diam. iron bolts with washers, as shown in Fig. 416.

At the two ends of the fights, 4"×4" newel posts are fixed and the strings are housed and pinned into them, as shown in the above figure.

A rough string or carrier of size 4″×3″ may be provided between the two strings. Treads are supported on this carrier by means of rough brackets 6″×1″ which are fixed alternatively, one on each side of the carrier. See Figs. 417 and 418.

The underside of the flight may be covered with ½″ lath and plaster or with ½″ ceiling, planks, as a finishing for the soffit. In such a case rough carriers are always recommended to avoid cracks in the finished soffit.

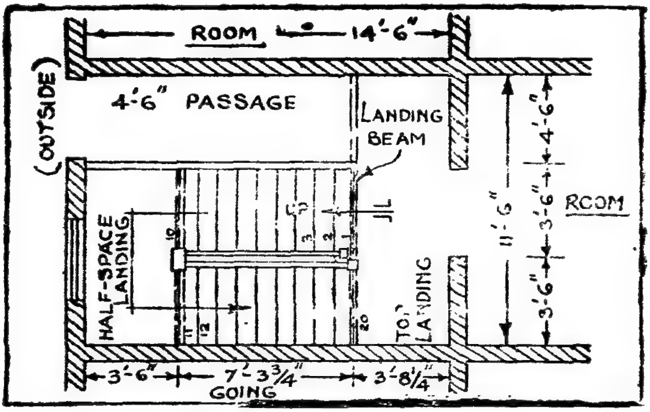


Fig. 419. Plan of a dog-legged stair.

(iii) *Landing*—At landing, a trimmer beam 8″×3″ is provided to support the newel post and the landing joists. The joinry work required in this connection is shown in Fig. 416. Similarly at top floor level, another landing beam will also be required.

A hand rail of suitable size and design is also provided. Some types of hand rails commonly adopted, are shown in Figs. 395, 396 and 397.

It may be noted that in places where noise due to persons moving over a stair has to be deadened, the steps and landings are covered with carpets or coir matting.

The entire arrangement of the staircase with the stair is shown in plan in Fig. 419.

TABLE No. IX
Details of Stairs.

Serial No.	Description.	Adopted Size
1	Height between finished floors	12'-9"
2	Size of stair-case room	13'-9" × 10'-6"
3	Number of flights	2 Nos.
4	Type of stair...	Dog legged
5	Width of stair	3'-6"
6	Horizontal span of string	7'-3$\frac{3}{4}$"
7	Size of housed string	10" × 2$\frac{1}{2}$"
8	Going	9$\frac{3}{4}$ ins.
9	Tread	11 ins.
10	Rise	6$\frac{1}{2}\frac{8}{0}$ ins.
11	Thickness of tread	1$\frac{1}{4}$ in.
12	Thickness of riser	$\frac{3}{4}$ in.
13	Sire of carriage	4" × 3"
14	Mid-landing beam. span 7'-0"	8" × 3"
15	Top landing beam, span 10'-6"	10" × 5"
16	Landing joists @ 12" c/c	4" × 2"
17	Nevel post	4" × 4"
18	Moulded hand-rail	4" × 3"

TABLE No. X
Loads on Stair

Type of stair	Distributed load in lbs. on each string per r. ft. of span. Width of stair.				
	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"
Domestic @ 80 lbs./s. ft. ...	120	140	160	180	200
Public @ 100 lbs./s. ft. ...	150	175	200	225	250

Art. 157. Loads on Stairs—Stairs in domestic buildings should be designed for loads not less than 80 lbs. per sq.

ft. For those in public buildings, this value should be increased to 100 lbs. per sq. ft. The following table gives the values of loads on the respective stairs for design purpose—

Art. 158. ·Illustrative Problem—*Design of Timber String.* Width of stair, 4'–6". Horizontal span of string 7'–6". For a public building, the load on the string will be 225 lbs./r. ft. distributed, Add dead load due to treads, risers, railing and self-load of the string @ 60 lbs./r. ft. Hence total load on string equal, 225 + 60 = 285 lbs./r. ft.

B. M. (max.) at centre of string

$$= 286 \times 7.5 \times 1.5$$

$$= 28900 \text{ in. lbs.}$$

Section modulus, $Z = \dfrac{28900}{1250} = 23.1$ in^3. Or $bd^2 = 6 \times$ 23.9 = 143.5 in.^{3}; where b and d are the breadth and depth of the stringer. Taking a width of $1\frac{1}{2}$ inch effective the depth of the string is given by,

$$\text{depth, } d = \frac{\sqrt{243.5}}{1\frac{1}{2}} = \sqrt{96}$$

$$= 10 \text{ inches say.}$$

For housed string an allowance of $\frac{3}{4}''$ should be made over the above width of $1\frac{3}{4}$ inches,

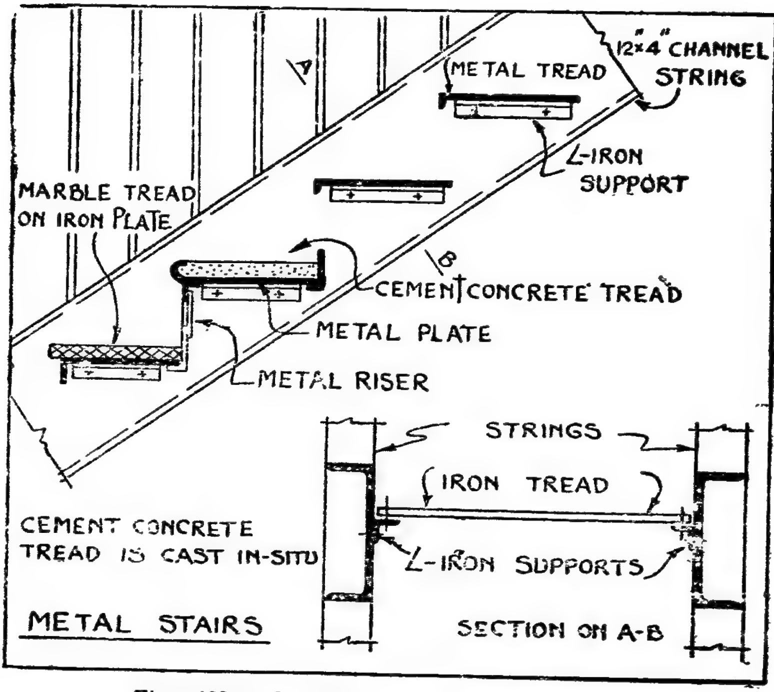
∴ Size of housed string required is $10'' \times 2\frac{1}{2}''$.

For a cut or open string, a width of 3 ins. may be taken for calculation, and a suitable increase is made over the designed depth. In this case it will be noticed that a very heavy section will be required. Thus cut strings become uneconomical for bigger spans and heavy loads.

Art. 159. Metal Stairs—Metal stairs are very commonly used in Mill-constructions, where rough wear and tear and fire-proof qualities are mainly required. The strings are of closed type. A metal stair in its simplest form consists of cast iron or rolled steel strings to which are fixed metal treads by means of angles at their ends. See Figs. 420 and 421

below. Metal balusters with pipe handrail or teak wood handrail are provided on the outer string.

Very often risers are omitted.



Figs. 420 and 421. Details of metal stairs.

The angles supporting the treads may be fixed to the string by means of rivets or they may be welded. Where better appearance is desirable, marble or polished stone treads may be laid on metal treads in cement. Sometimes concrete treads are cast on metal treads and a metal nosing is provided in addition.

Metal stairs are obtained in stock patterns for different dimensions and spans, from the manufacturers. They are usually designed for heavy loads. Treads are also made of bronze, aluminum and nickel with specially treated surfaces to give hard and non-slip surface, and also to increase their strength and durability.

Spiral stair of cast iron is another form of metal stair very commonly used for service purposes in public as well as residential buildings. In power-houses and pumping stations, this type of stair has very wide application,

Art. 160. Reinforced Concrete Stairs—Plain concrete steps are used when they have a solid backing or when they rest on firm ground. But even in such cases, it is advisable to use some form of reinforcement to prevent cracking from settlement.

Reinforced concrete stairs fall into two distinct catagories.—

(i) A stair when steps are designed to bridge across the two end strings which act as inclined R.C.C. beams.

(ii) A slab design where each flight is designed to act as one inclined slab whose width equals to the width of the stair.

In each of the above two types, the inclined beams or the inclined slab span from floor to floor or from floor to intermediate landing, or from landing to landing. Sometimes the inclined slabs include the width of landing in their span length.

Concrete stairs resist wear and tear, and possess fire-resisting qualities. They can be cast to any required shape. The treads and risers of concrete stairs are finished either cast-in-situ or in any other way by providing marble, or polished stone, as mentioned in Article 138. The provision of form work requires special attention and has to be carried out accurately during the construction of an R. C. C. stair.

Art. 161. Illustrative problem—

R. C. C, stair, Slab type. See Figs. 422 and 423,

Tread .. = 11″ (going)
Rise .. = 6″
Effective span = 9′ – 3″

Loads and Bending Moments—Live load @ 100 lbs/sq. ft. equals $9.25 \times 100 = 925$ lbs. per foot width of stair slab.

$$B.\ M_1 = 925 \times 9.25 \times 1.5$$
$$= 12850 \text{ in. lbs.}$$

Dead load equals 33 lbs. (due to step) + 78 lbs. (due to waist) + 9 lbs. (due to finish) = 120 lbs. per step. Since there are 10 treads, dead load equals $120 \times 10 = 1200$ lbs. per foot width of stair slab.

$$B.\ M_2 = 1200 \times 9.25 \times 1.5$$
$$= 16600 \text{ in. lbs.}$$

Total bending moment equals $12850 + 16600 = 29450$ in. lbs. per foot width of stair slab,

Thickness of waist, effective, equals

$$d = \sqrt{\frac{29450}{127 \times 12}} = 4.4 \text{ ins.}$$

Lever arm = $0.88 \times 4.4 = 3.87$ ins. Over-all waist thickness is 6 ins.

Main longitudinal reinforcement,

$$\text{Area of steel, } A = \frac{29450}{18000 \times 3.87} = 0.42 \text{ sq. ins.}$$

Use $\frac{1}{2}$"rods @ $4\frac{1}{2}$ c/c.

Alternate rods are bent up. Distribution steel is used @ 3/8" under each step.

The plan and sectional elevation of the above R. C. C. stair are shown in Figs. 422 and 423.

Atr. 162. Illustrasive Problem—*R. C. C. Stair With Strings*—Height between floors is 10'—0". Going = 11": Rise=6"-Therefore horizontal span =17'-5". Width=4'-o"

(i) *Design of Steps.*

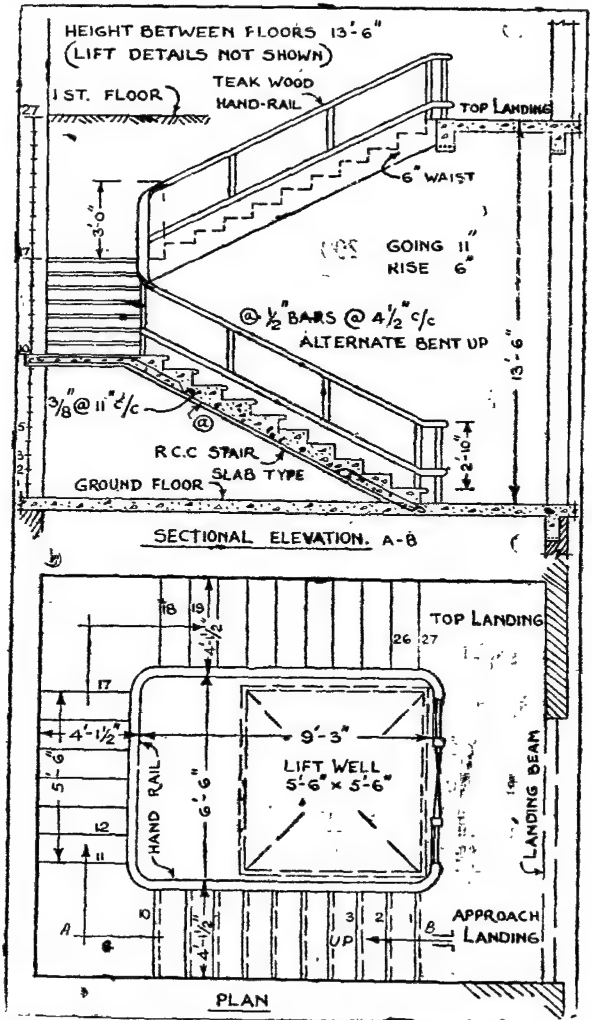
Loads and Bending Moment—33 lbs, (step) + 39 lbs. (waist) + 24 lbs. (finish) = 96 lbs. dead load/r. ft. of step.

B. $M._{-} = 96 \times 4 \times 4 \times 1.5 = 2300$ in. lbs.

Live load @ 300 lbs, per step. centrally placed.

$B.\ M._3 = \frac{1}{4} \times 300 \times 4 \times 12 = 3600$ in. lbs.

Total $B.\ M. = 2300 + 3600 = 5900$ in. lbs.

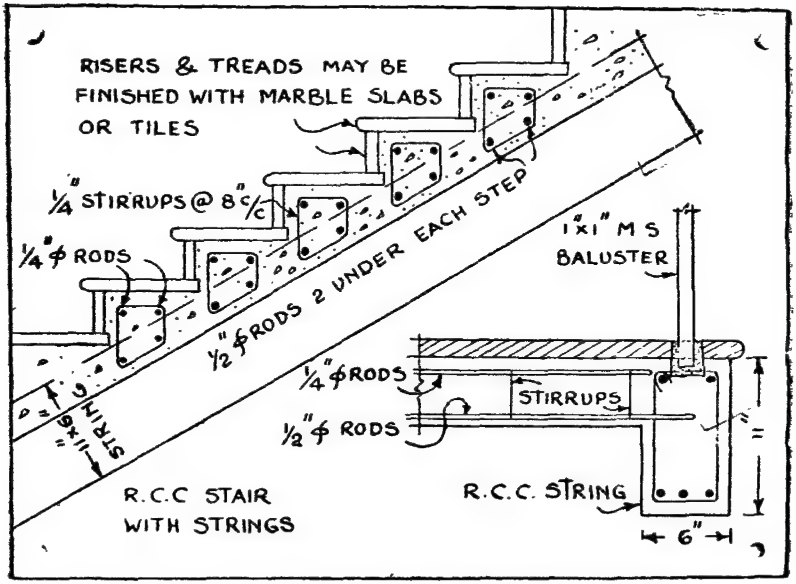


Figs. 422 and 423. Details of R. C. C. stair slab design.

This requires a value of $d = 2.5$ ins. effective or 3 ins. over all thickness of waist for each step.

Reinforcement required is @ $2 - \frac{3}{4}''$ bars under each step, but $2 - \frac{1}{2}''$ bars are provided.

(ii) *Design of String*-Dead loads, on eace string = 96 × 2 = 192 lb. + 66 lb.(self) + 15 lb. (hand rail) = 273 lbs. per step or 300 lbs. per r. ft.



Figs. 424 and 426. Details of R. C. C. Stair with R. C. C--strings.

Live load @ 100 lbs. per s. ft.=200 lbs per string per r. ft.

Hence total load = 500 lbs./r. ft.

B. M. = 500 × 17.4 × 1.5 = 72700 in. lbs.

This requires a depth of 9.57" effective or 11" over-all. The width of the string is taken as 6 ins.

∴ Adopted size of string 11"×6"

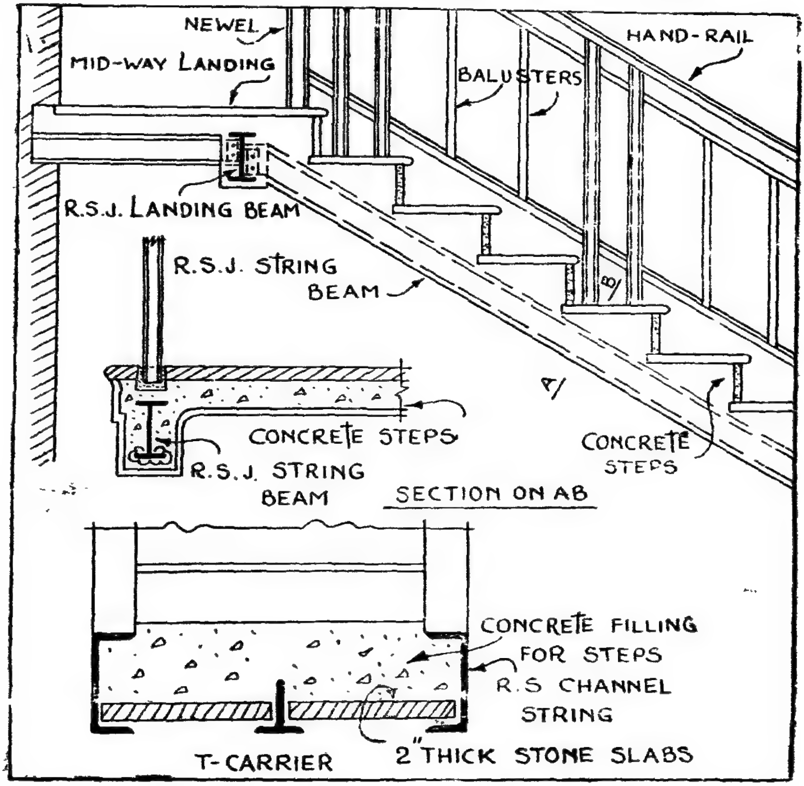
3 - ½" rods sufficient as main longitudinal steel.

The complete arrangement of this type of stair is shown in Figs. 424 and 425.

Art. 163. Composite Stairs—Composite Stairs are sometimes constructed with metal strings and concrete steps with soffits of flag stones. The tops of treads may be finished with ¾" cement plaster, or additional pieces of marble

15

or tiles may be provided. One type of such a stair is shown in Fig. 426. In Fig. 427 a section across the flight is also shown. It will be noticed that intermediate T—carriers are provided to support the flag stones at the soffit.



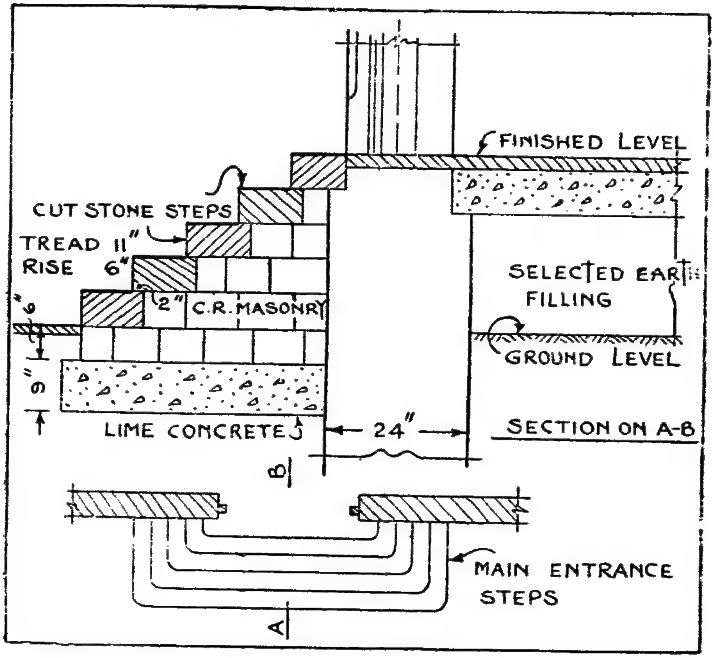
Figs. 426 to 428. Details of composite Stairs.

The metal strings which are usually rolled steel sections, either I-sections or channel section, are sometimes embedded with cement concrete as shown in Fig. 428.

Art. 164. Stone Steps and Stairs—Stone steps are built in three main types—

(i) Rectangular type;
(ii) Built-up type, and;
(iii) Spandril type.

Stone is a suitable material for stairs, but it should be selected of a strong, hard and durable variety. The steps leading to the ground floor of a building from the ground level are usually of stone.



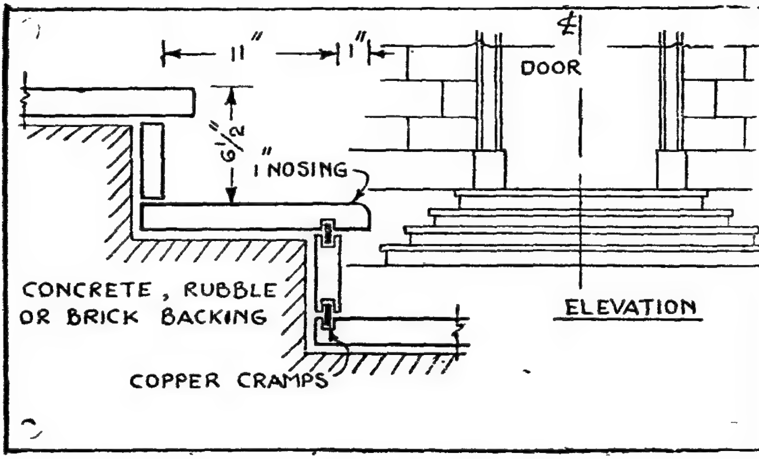
Figs. 429 and 430. Rectangular or square stone steps.

(i) *Rectangulare or Squaro Steps*—Figs. 429 and 430 show this type of steps. Each step is a solid square stone in section and rests on the top back of the step below it. The backing may be either of stone masonry or of brick.

(ii) *Built-up Steps*—The treads and risers are formed of independent thin slabs of stone as in the case of wooden step. See Figs. 431 and 432. Usually the slabs are 2 ins. thick and are firmly held in position by dowels, and cramps laid in cement mortar.

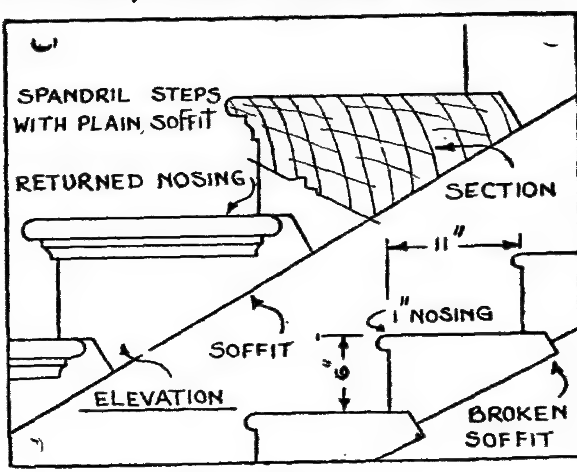
(iii) S*pandril Steps*—When a regular flight has to be constructed between the floors, spandril steps of stone are used. Each step is approximately triangular in section and

has its one end square which is built into the wall. The steps are rebated to put one over the other, the rebate being



Figs. 431 and 432. Built-up steps.

arranged at right augles to the soffit. The soffit may be either continuous, broken or moulded. Sometimes the steps



Figs. 433 and 434. Spandril steps.

are given a returned nosing. Spandril steps may also be supported at both their ends either by means of a wall or a steel section. The various details of spandril steps are shown in Figs. 433 and 434.

CHAPTER XIII

Composite Floors

(Fire–Resisting Construction)

Steel and concrete floors. Double flag stone floors. Jack arch floors. Filler joist floors-floor finishings. Solid and hollow tile arch floors. Flat floors of clay tiles. Expanded metal rib-mesh floors-Jack arch and flat type. Continuous floors-expanded metal and rib-met type R. C. C. floors-beam and slab type; girderless type. precast R. C. C. Floors.

In this Chapter the constructions of composit floors with materials like, steel concrete simple and reinforced. bricks, and specially shapped clay producte, etc., will be described.

Art. 165. Steel and Concrete Floors—Owing to its inflammable quality the use of timber cannot be specified for construction when fire resisting properties of building have to be mainly attended to. Similarly when greater spans and heavier loads have to be dealt with in a design, steel and concrete are widely used, on account of their strength and the consequent smaller sections. In these cases timber sections become heavy and uneconomical. This limits the use of timber as a main constructional material in a a modern building. Steel in various forms is used in combinaticn with concrete in the construction of floors of buildings, particularly when durability and fire-resisting qualities are needed.

Steel and concrete floors also admit of great compactness. and flexibility of design which are not possible in timer floors.

The framed structares that are now adopted in the design of modern buildings, also damand a free use of steel and concrete, as these materials are generally the best suited ones for their frame work of columns, beams and floors. Sometimes clay products such as bricks of different shapes, usually hollow and specially moulded for the purpose, are employed with steel and concrete in many proprietory floors. Composite floors are also constructed with steel sections,

flag stones and concrete. It may be mentioned that these floors, on accunt of their general homogeneous character, are rigid and behave satisfactorily under heavy loads.

Art. 166. Double Flag Stone Floors—A simple form of floor construction where steel sections are used with flag stones is shown in Fig. 435,

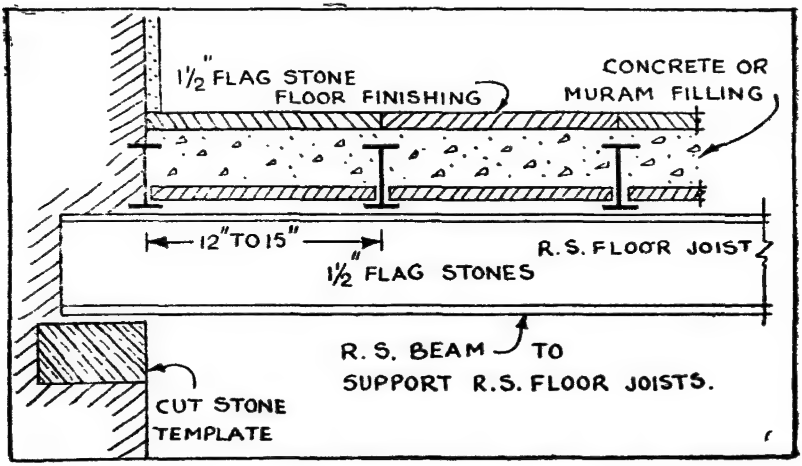


Fig. 435. Double flag stone flooring.

The rolled steel joists are placed at a spacing of 15 ins. to 21 ins. c/c, and the lower layer of flag stones is placed on the lower flanges of these joists. Concrete or murum is fllled on top of this layer, and is well watered and rammed. The top layer of flag stones is then laid on this murum filling. The flag stones are properly jointed with mortar and are finally pointed in cement mortar. In its simple form of consrruction, the lower layer of flag stones and the concrete filling are omitted.

Sometimes inverted T-sections are also used for flag stone floors, the lower layer of flag stones being supported on the flanges of the T-section. The top layers of flag stone may be replaced by any other type of floor flnishing described later.

Art. 167. Illustrative Problem—Calculate the size of the steel joists to support double flag stone flooring shown in Fig. 435. Span of the joists is 11'–0" and the working stress in steel is $f = 8$ tons/sq. in. in compression and in tension. Modulus of elasticity is 13500 tons./sq. in.

Solution. (i) **Loads.**

Live load	.. , . ..	80 lb./sq. in.
Dead load,		
(*a*) Due to flag stones at 12 lbs./in thickness	... ...	30 ,, ,,
(*b*) Due to murum flling at 8 lbs./in. thickness. 4" filling between flag stones is assumed,	...	32 ,, ,,
(*c*) Due to joist load	... ...	8 ,, ,,
	Total load $W =$	150 lbs./sq. in.

(ii) *Section Modulus. Z.*

Flag stones are availble in various sizes; for any one floor, they should be of the same width so that centre to centre spacing of the joists is constant. In this case 15" c/c spacing is taken.

$$\therefore \text{ Load on each joist is, } 150 \times 1.25 = 188 \text{ lbs./ r. ft.}$$

$$\text{Total load} = 188 \times 11 = 2070 \text{ lbs.} = 0{\cdot}93 \text{ ton per joist.}$$

$$B.\ M. = \frac{wl^2}{8} = 188 \times 11 \times 11 \times 1.5$$

$$= 34000 \text{ in. lbs,} = 15.2 \text{ in. tons.}$$

$$\text{Section modulus, } Z = \frac{B.\ M.}{f}$$

$$= \frac{15.2}{8} = 1.9 \text{ in}^3.$$

From the table it will be seen that $4\frac{3}{4}" \times 1\frac{3}{4}"$ size is suitable. Modulus of the section = 2.83 in.^{3}; Permissible load for 11 feet span is 1.1 ton per joist.

Weight = 6.5 lbs./r. ft.

Moment of Inertia, $x.x = 6.73$ in.^{4}

(iii) *Deflection*—The designed section should possess stiffness as well as strength and therefore it should be tested for deflection also. The central span deflection for each joist is given by,—

$$d = \frac{5}{384} \cdot \frac{0.93 \times 11^3 \times 12^3}{13500 \times 6.73} = \mathbf{0.3\ inch.}$$

$$= \frac{0.3}{11 \times 12} = \frac{1}{440} \text{ of span.}$$

which is permissible.

(iv) *Shear Stress*—Assuming that all the shear is taken by the web, we have,

Intensity of average shear stress,

$$s = \frac{0.93}{0.18 \times 4.1} = 1.26 \text{ tons./sq. in.}$$

where, web thickness = 6.18 inch, and

depth of web. = 4.75 − × 20.325

= 4.1 inch.

Art. 168. Jack Arch Floor—In Figs. 436 to 438 one illustrated a method of constructing jack arch flooring, where concrete forms the main body of the floor and is used in the form of arches spanning between steel joists. These arches are known as concrete jack arches and their span varies from 2′-0″ to 4′-0″. The rise is usually kept at 1 inch por foot of span. The thickness of the arch should not be less than 3″ at the crown, and the R. S. joists should have a cover of at least 1½″ on their top flange.

Construction of Jack Arch Flooring–For the construction of this floor the R. S. Joists are first placed on the walls at the required spacings and the arches of conorete are then cast. While laying concrete for the arches, the haunches are filled in, and then then the sides and crown portions upto the specified thickness. The floor finishing is finally laid.

Centering for Jack Arches—There are various types of centering for casting jack arch concrete. They are convenie-ntly supporteds on the lower flange of the R.S. Joists and are struck off readily after the concrete is set. In one form the

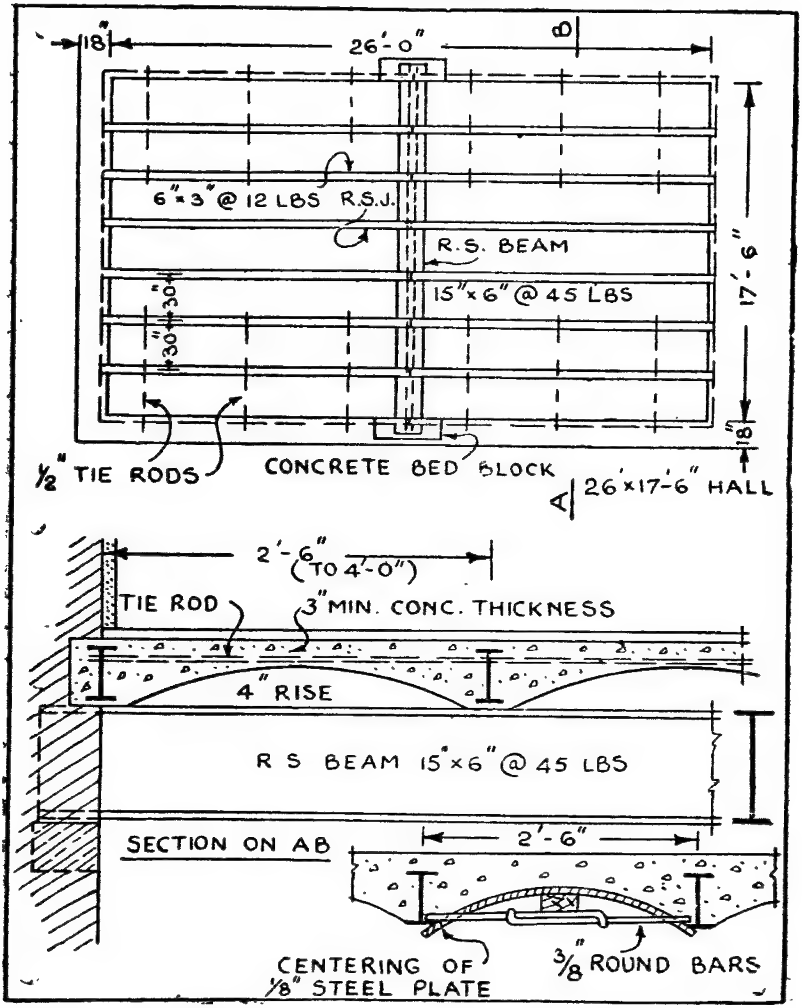


Fig. 436. Plan showing the general lay out of the R. S. beam and R. S. joists for the jack arch flooring.

Fig. 437. Section on A--B showing the jack arches and tie rod.

Fig. 438. Centering for jack arches.

centering consists of $\frac{1}{8}''$ steel plate bent to the exact shape of the intrados, and is held in position by a pair of 3/8" round bars. The bars are provide with eyes at one end, as shown in Fig. 438. The central portion of the centering plate is supported by a block of wood.

Art. 169. Illustrative Problem—What size of R. S. Js. should be specified to support the concrete jack arches for the floor of a residential building, if the span of the arches is 3 feet, and that of the R. S. J^s, is 12 feet ?

Solution—Assuming an average thickness of 6" for the floor, including $1\frac{1}{2}''$ tiled finishing on top, it will be seen that the total load coming on each R. S. Joist, including its own weight @ 11 lbs./r. ft., is (66+11+80) = 157 lbs./sq. ft. = 157 × 3 = 471 lbs./r. ft.

$$\text{B. M.} = 471 \times 12 \times 12 \times 1.5 = 1{,}08{,}000 \text{ in. lbs.}$$
$$= 45.3 \text{ in. tons.}$$

$$\text{Section Modulus, } Z = \frac{45.3}{8} = 5.66 \text{ in.}^3$$

Use 6" × 3" @ 11 lbs. R. S. Joists.

The section should also be tested for deflection and shear. The arrangement of the floor system is shown in Fig. 436 and 437.

Tie Rods—Jack arches exert lateral thrust on the walls. They should therefore be tied down by tie bolts $\frac{1}{2}''$ to $\frac{5}{8}''$ diam. for the end two or three spans. One end of the tie rod is fixed in the wall with an anchor plate and the other end is fastened to the R, S. J., with a bolt as shown in Figs. 436 and 437.

It will also be noted that on account of the rise to be given to the jack arches, such floors increase the height of a building.

Art. 179. Filler Joist Floors—(*a*) Rolled steel joists can also be used for constructing flat reinforced concrete slab floor. They are embedded in concrete as shown in Fig. 439, and act as reinforcement. For casting such floor, it is necessary

to first erect the centering and then lay the R. S. Joist at the required spacing. It should be noted that proper coverings of concrete should be provided for the R. S. Joists at top and bottom, and they should preferably be held in position at the

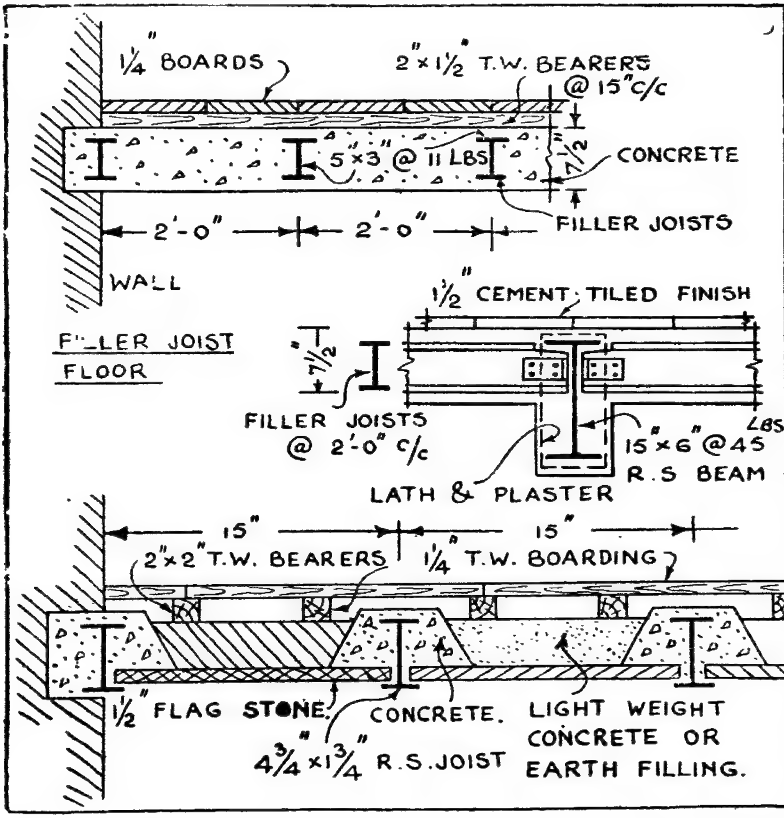


Fig. 439. Filler joist floor with teak wood finishing.
Fig. 440. Showing the method of web connection of filler joists of the R. S. bean supporting them. The R. S. beam is encased in concrete with lath and plaster. Cement tiled finish is provided on top.

Fig. 441. Another type of flat concrete floor.

required spacing with the aid of tie rods passing through the web. Sometimes old rails are also used as reinforcement and thus the cost of the rail is reduced.

For spans upto 12 ft. the spacing of the joist may be kept as 18″ to 24″. Usually heavier loads require shorter spacings. For spans larger than 12 feet, some type of transverse reinforcement should be used for concrete between the joists as explained later.

Floor Finishing—(i) Fig. 439 is illustrated the method of providing timber finishing on concrete floors. 2″ × 2″ teak wood beares are fixed by means of clips. at 15" c/c and teak wood boarding is laid across them.

(ii) In another method, the floor finishing may consist of cement tiles, as shown in Fig. 440. In ordinary case, the floor finishing may consist of a layer of ¾″ cement plaster.

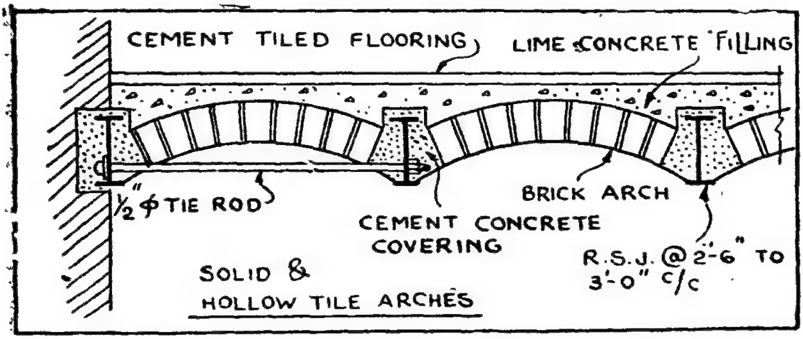


Fig. 442 Showing method of constructing solid and hollow tile arches.

(*b*) In Fig. 441 is illustrated a modified method of constructing composite floors where R. S. Joists are embedded in cement concrete separately and flag stones are laid between them on their lower flanges, as in the case of double flag stone flooring. On top of flag stones, light weight concrete or earth is filled and well-rammed. The finishing on this may be of any type mentioned above.

Art. 171. Hollow Tile Arch Floors—Steel beams aret used in eombination with hollow tiles in the construction of arched floors. See Fig. 442. Rolled steel joists are placed a0 the required spacings which usually vary from 2′–6″ to 4′–″,

and are encased with cement concrete as shown. Hollow tiles specially moulded for the purpose are arranged in the form of arches between these R. S. Joists. On top of these arches a filling of lime concrete is laid to the required thickness. The floor finishing may consist of a paving of cement tiles or simply of a ¾" cement plaster properly ruled as per design. Alternatively when the substructure of the floor, viz.. R. S. joists and hollow clay tile arching together with the lime concrete filling is ready, any other desired floor finishing may be laid on it. The last arch or two arches should be provided as usual with tie rods at 3 to 4 feet centres. Sometimes the

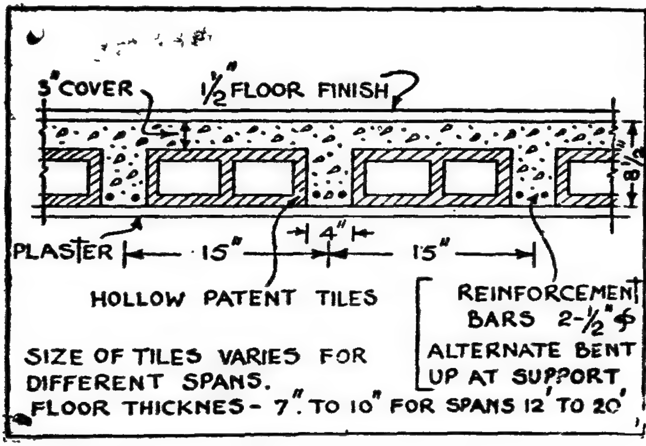


Fig. 443. Flat floors of hollow clay tiles of rectangular variety.

lower portions of the R. S. Joists are encased with specially moulded bricks, instead of cement concrete; and the lime concrete is replaced by 1 : 3 : 6 or 1 : 8 cement concrete.

(ii) *Solid Brick Jack Arches*—A similar method of construction as detailed above is adopted for the construction of solid brick jack arch floors in combination with steel joists, except that solid bricks are used instead of hollow clay tiles. See the same figure.

Art. 172. Flat Floors of Clay Tiles—Several varieties of proprietary floors are now available in the market. In one veriety rectangular hollow patent clay tiles are employed

in combination with reinforced cement concrete which forms an inverted channel section as shown in Fig. 443. The over-all thickness of the floor varies from 7" to 10" for spans from 12 to 20'. In some cases the reinforced concrete ribs between the hollow tiles are replaced by rolled steel sections as shown in figs. 444 to 448. Two types of hollow clay tiles are shown in the above figures, the rectangular type and the traingular type. Main beams and rolled stell joists are used in the cons-

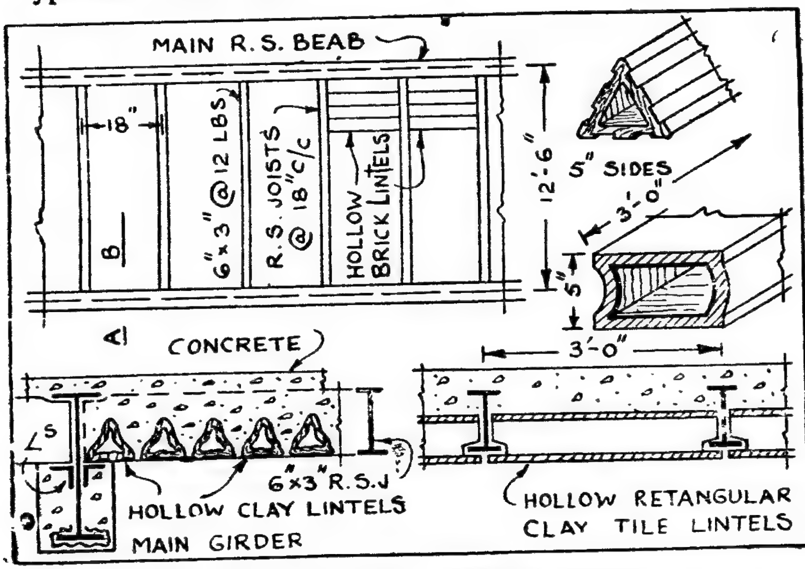


Fig. 444 to 448. Details showing the method of constructing flat floors of triangular and rectangular hollow clay tiles.

truction of such floors and the hollow clay tiles span the distance between the R. S. Joists as lintels. These floors do not require any centering. As usual a layer of concrete is laid on top of these tiles to provide a bearing surface for floor finishing.

Art. 173. Expanded Meta Rib-mesh Floors—(i) Special type of reinforcement known as *Z*—type ribmet, is employed to construct jack arch floors of concrcte as shown in Fig. 449. The normal rolled steel joists are placed at the

required spacings and the Z—type ribmet is laid in the from of an arch between these joists. Cement concrete is then laid on top of this ribmet reinforcement to the required thickness. At the under side of the joist and around the lower flange, B. B. lathing is flxed and the entire soffit of the floor is finally rendered with a coat of cement plaster.

(ii) Ribmet floors can be also cast with a horizontal soffit. X–type ribmet is spread horizontally to span between the R. S, joists as shown in Fig. 450. The ribmet reinforcement rests directly on the top of the lower flanges. Other

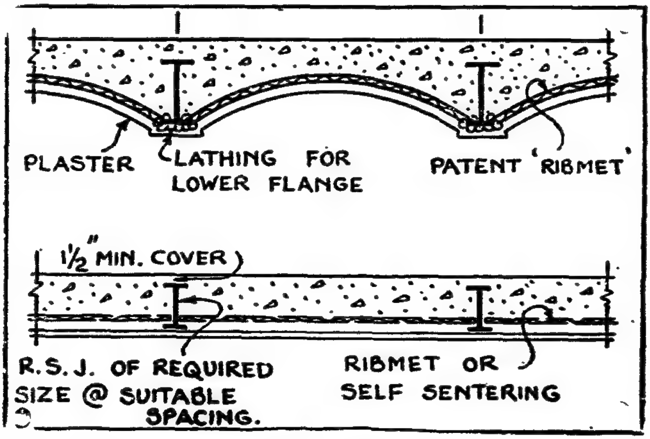


Fig. 449, Expanded metal rib-mesa floots-Jack arch type
Fig. 450, Expanded matal rib-mesh flate floors.

principles of construction are the same as those adopted for Z—type ribmet jack arch flooring detailed above.

From the strcutural point of view, these floors act as independent or noncontinuous units or slabs between the rolled joists.

Art. 174. Continuous Floors of Expanded Metal Rib-mesh—(i) A simple type of continuous floor is shown in Fig 451. It will be noticed that the rolled steel joists are replaced by reinforced cement concrete T—ribs and a concrete slab of the required thickness is cast monolithically with these ribs. The usual placing for these ribs varies from 16″ to 24″

and the depth of the T—ribs varies from 6″ to 12″ below the underside of the concrete slab. Correspondingly a slab thickness of 2″ to 4″ should be provided for the respective spans. A flat continuous ceiling of hy-rib and plaster is

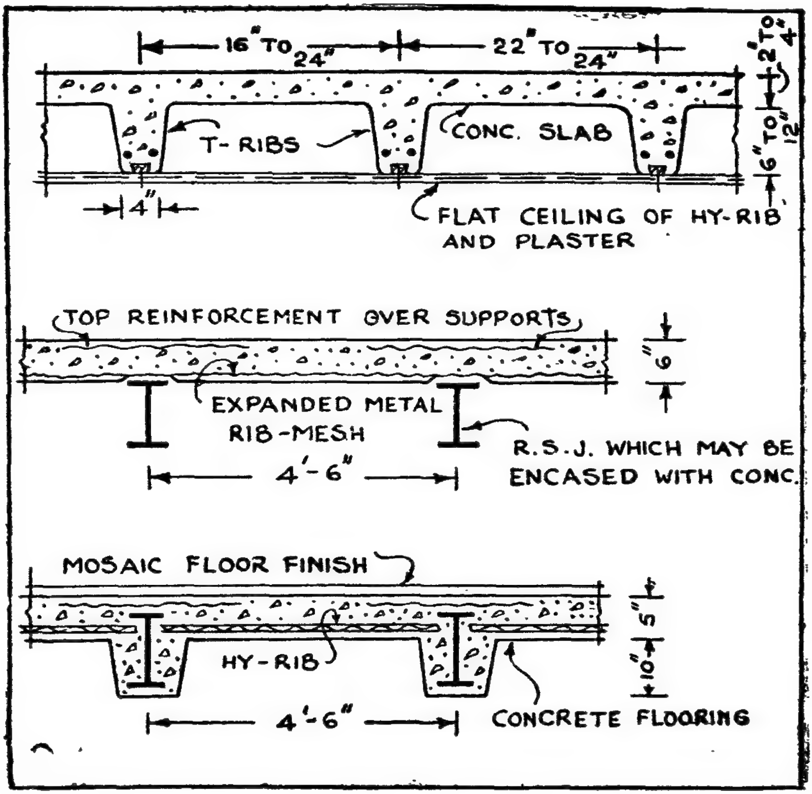
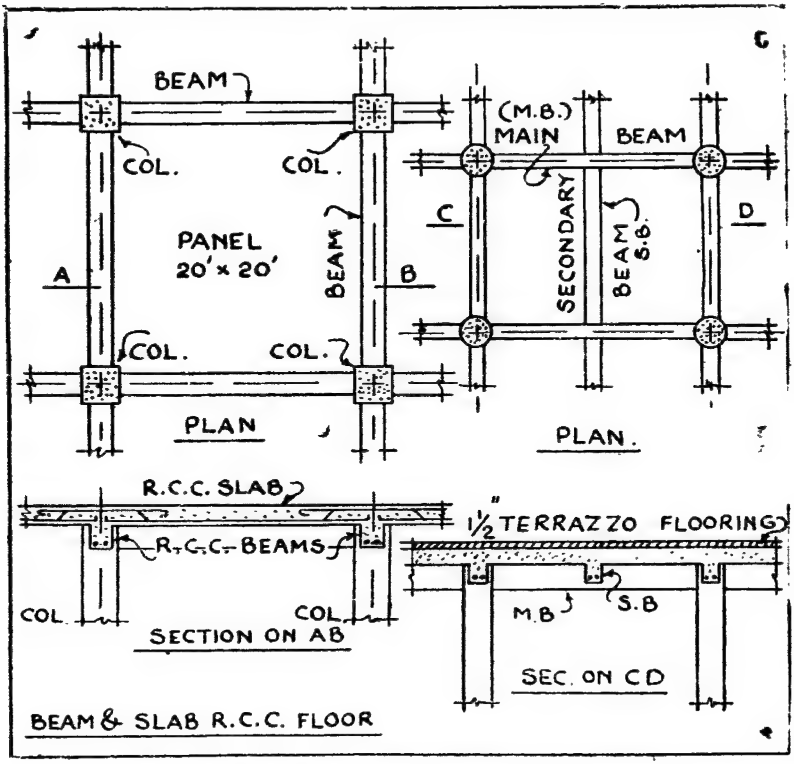


Fig. 451. Ribbed continuous floors of reinforced concrete.
Fig. 452 and 453. Different types of continuous floors of expanded metal rib-mesh.

hung at the underside of the T—ribs with the aid of teak wood fillet pieces as shown in the above figure.

(ii) Sometimes the T-ribs of reinforced concrete are replaced by R. S. Joists and a continuous slab is laid on top of them. See Fig. 452. A continuous layer of expanded

rib-menesh is placed on the top flange of the R S. Joist to take up the bottom tension in the slab, while indepent strips of top reinforcement is placed over the supports to take up the top tension in the slab due to negative bending moment at these points. The spacing of the R. S. Joists may beincrased to 4′—6″ for these floors. Concrete is then placed on the



Figs. 454 to 457. Beam and slab R. C. C. Floors.

R. S. Joists to encase the bottom and to preinforcements. The thickess of the: concrete should normally be not less than 6″ for heavy floors and 4½″ for ordinary floors.

(iii) The rolled steel joists mentioned in the above type of floor are sometimes encased with cement concrete and the expanded metal reinforcement placed slightly below

their top flange. See Fig. 453. The top reinforcements over the supports placed above the top flange as required to form a continuous floor.

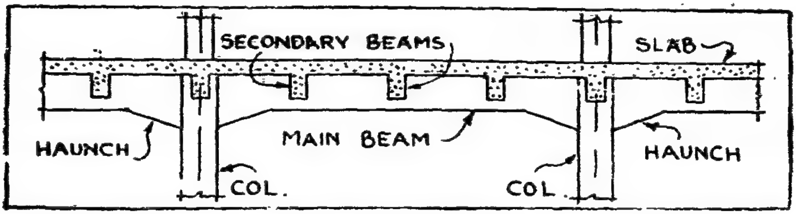


Fig. 453. Beam and slab slab R C.C. floor with three secondery beams,

Art. 175. R. C. C. Floors—The special type of reinforcement for the concrete slab resting on the rolled steel joist mentioned hitherto in Arts. 164 and 165 may be replaced by steel rod reinforcement to form an R. C. C. slab. Sometimes B. R. C. fabric is also employed for steel reinforcement.

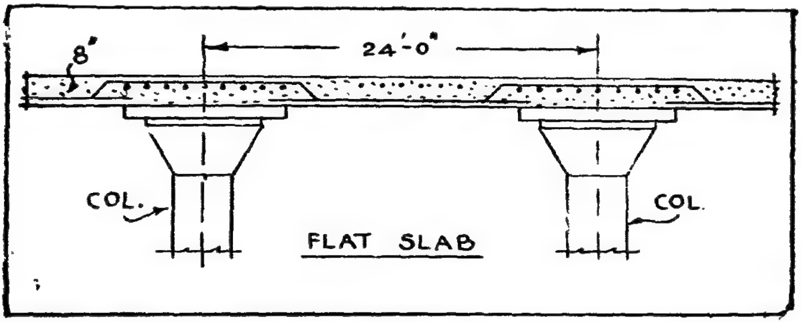


Fig. 458. Girder-less or flat- slab R. C. C. Floors.

(i) *Beam and Slab R. C. C. Floor*—Diffent types of beam and slab R. C. C. floors are shown in Figs. 454 to 457. The beams supporting the slab rest on the columns whic are so located as to form economical floor panels. The panels may be square or rectangular and between the columns there may be one or more than one panels. In the latter case secondary beams are introduced to rest on the main beams. In Fig. 458 the section of a floor with three secondary beams is shown.

(ii) *Girder-less or Flat Slab, R.C.C. Floor*—In another type of R.C.C. floors, beams and girders are eliminated, and the slabs are designed to rest directly on columns. Such floors are called flat slab floors. The columns supporting flat slabs are circular in section and a column capital or head is provided at their top to receive the slab. In the dropped panel type of flat slab a portion of the slab around the column capital is cast slightly thicker than the rest of the slab. See Fig. 459

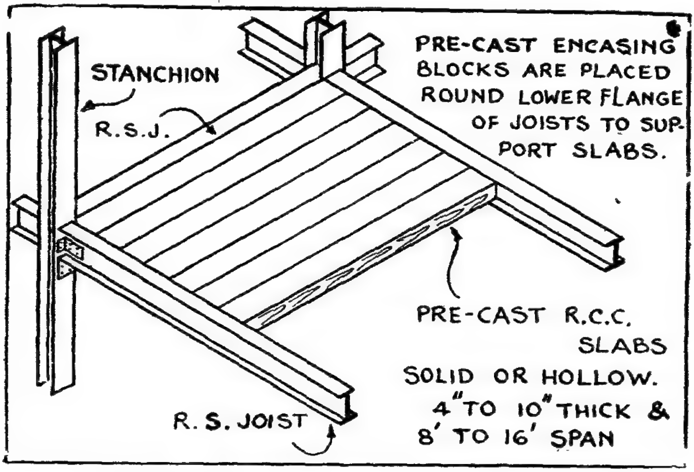


Fig. 460. Pre-cast R. C. C. slab floors.

Construction of Cast In-situ R. C. C. Floor—The following is the brief description of the sequence followed in the construction of cast in-situ type of R. C. C. floors.

(a) A False Work or Centering should be erected first to support the beams and slabs during and after construction until concrete becomes self supporting. The false work may be either of timber or of steel and in either case it should be sufficiently strong and of the correct dimensions of the finished floor. Facility for erection and for striking-off should be the main features in their design.

(*b*) *Placing Reinforcement*—After the form work is ready and the joints in it are examined for leakage the

surface which comes in contact with concrete is given a thin coat of oil to prevent concrete from adhering to it. The beam and slab reinforcements are then placed in position as per detailed drawings pertaining to the slab. Proper precaution should be taken to see that steel reinforcement is free from rust or greezy matter and is embedded well in concrete. This is ensured by giving a cover of the requred thicknes outside the rods.

(*c*) *Laying Concrete*—Concrete of the required strength and consistancy is then placed around the rcinforcement and for the required thickness of the slab.

(*d*) *Curing and Striking-off Form Work*—Concrete is then given sufficient time to harden by keeping it wet for 10 to 15 days. Finally the form work is struck off and the soffits of slabs and beams are treated as specified.

Art. 176. Pre-cast R. C. C. Slab Floors—Solid or hollow pre-cast R. C. C. slabs are employed in the construction of these floors. Very often pre-cast slabs of the required dimensions for different spans are available. The slabs are placed between the rolled steel joists lengthwise to span the distance as shown in Fig. 460. Cement mortar is used to grout the joints and the floor finishing may be of any one type hitherto mentioned. These floors are consructed quickly as compared to cast in-situ floors.

CHAPTER XIV

Timber Roofs

Purpose and function of roofs. Types of roofs--pitched roofs and flat roofs. Common terms used in roof construction. Different types of rafters. Eaves board, perlins, wall plates and post plates. valleys and ridges. Trimming.

Structural aspects of roofs. Single roofs, double recfs, and trussed roofs. Lean to roofs; couple roofs, couple close roofs; Double roofs or purlin roofs. llustrative problem, Trussed roofs. king post and Queen-post trusses. Various joints in trusses. parapet ends and eaves ends. Purlin rafter and common rafter construction, Combinatton trusses. Mansard roof truss.

Art. 177. Roofs—their Puprose and Function— The tops of buildings are provided with coverings, commonly known as *Roofs*, evidently for the general purpose of keeping out rain, sun and wind, and to protect their interior from exposure to weather. This has also an effect on increasing the life of a building. A roof, therefore, must be designed and constructed to meet the requirements of climates in different parts of a country

From the structural point of view, a roof should be so designed and constructed as to strengthen the walls at their top and add to their stability. Asthetically roofs also add to the appearance of a building.

Art. 178. Types of Roofs—Roofs are constructed with their surface either flat or inclined at a suitable angle, and are accordingly classified into two main divisions,—

(i) Flat Roofs; and.

(ii) Pitched Roofs, or Sloping Roofs.

This division is mainly based on the climatic conditions of a locality, the materials available for roof coverings, and the appearance required for the building. Though flat roofs are very common in parts of the country where the climate is

hot, their use is mainly intened to make the roof area available for use to the occupants, Sloped roofs hvae a distinct advantage of thowing off the rain water readily, and in preventing the accumulation of snow in very cold countries.

The slopes given to roofs for draining away the rain water depend upon the materials used for roof coverings. The slopes should be sufficient to prevent the water peneting through the joints. Where a continuous surfacing free from joints is used, as in the case of flat roofs, a slope of 1 in 10 to 1 in 80 is usually enough. Pitched roofs are given slopes varying from 1 in 1½ to 1 in 2. If tiles are used as roofing materials, steeper slope should be given on account of their flatness and the greater number of joints between the tiles Below is a table of slopes suitable for various roof coverings.

TABLE NO. XI

Common Roofing Materials and Slopes to be Given for Their Surfaces.

Roof Covering	Weight per foot Super	Angle of Slop	Ratio of rise to Span
Flat Roofs			
Asphalt per 1 inch thick...	12 lbs.	1°-00	1 in 60 to
Concrete per inch thick...	12 lbs.	2-°00	1 in 30
Corrugated iron ...	2 lbs.		1 in 4
18 No. to 24 No. ...	to	26°-30′	to
or asbestos sheet ...	7 lbs.		1 in 8
Slate laid in position			
⅜" thick ...	15 lbs.	26°-30′	1 in 4
½" thick ...	20 lbs.	do	do
Mangalore tiles ...	10 lbs.	33°-30	1 in 3
Country tiles one layer ...	7 lbs.	35°-00	1 in 3
two layers ...	14 lbs.	35°-03	1 in 2

Art. 179. Common Terms used in Roof Construction–

The following are the common terms used in the roof construction:—

(i) *Common Rafters*—These are members supporting

thebattons or boardings to support roof coverings. They run from ridge to eaves. Their usual size is 3″ × 3″ for spans upto 6 feet and 5″ × 2″ for spans upto 10 feet; their centre to centre spacing varying from 15 to 18 inches. See Fig. 461 for common rafters. See Table No. XII for the size of common rafters for different spans.

TABLE No. XII

Minimum Size of Common Rafters Spaced ai 18″ Centre to Centre

Serial no	Unsupported length of rafter	Size of rafter
1	6 feet	2 ins. × 3 ins.
2	7 feet	2 ins. × $3\frac{1}{2}$ ins.
3	8 feet	2 ins. × 4 ins.
4	9 feet	2 ins. × $4\frac{1}{2}$ ins.
5	10 feet	2 ins. × 5 ins.

(ii) *Jack Rafters*—These extend from hip or valley pieces to the eaves. They are shorter than eommon rafters and are marked by JR in Fig. 461. A hip or valley is formed by the meeting of jack rafters.

(iii) *Ridge Piece*—This is a piece which runs horizontally at the highest point in the roof. Its Size is usually 2″ × 5″ though sometimes 2″ × 7″ is also used. The ridge is marked by *R* in the above figure. The common rafters abutt against the ridge piece are fixed to it. *Ridge* is a term applied to the line of a roof where the opposite slopes meet. See Fig. 461 showing the various terms used for pitched roofs.

(iv) *Hip Rafters* are those that form the hip of a roof. The upper ends of common rafters and the end of purlins also are fixed to hip rafters. Over a hip rafter the roof forms triangular sloping surface and is called a hipped end. The size of a hip rafter is usually 2″ × 7″.

(v) *Valley Rafter*—A valley is formed by the intersection of two roof planes sloping downwards towards their junction. The external angle thus formed is less then 180°. Along the valley line is laid the valley rafter to fixd the feet of jack rafters and the ends of purlins.

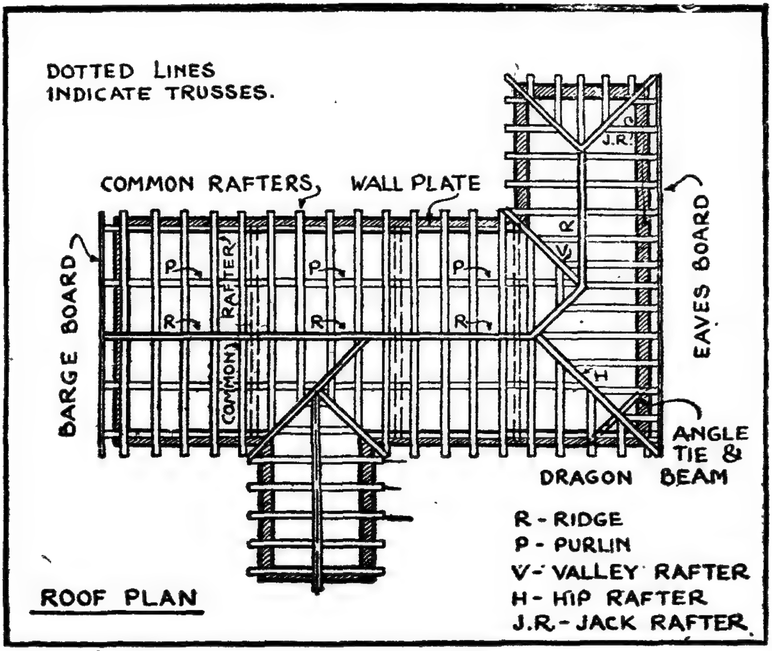


Fig. 461. General plan of a pitched roof showing component parts.

(vi) *Dragon Tie*—The hip rafters require special fixing at their ends when they are heavy, since they run in a sloping direction from the ridge to the corners. A special timber piece is laid diagonally under the hip rafter at its lower end across the corner of the walls. This is termed as a dragon tie and is fixed to the wall plates on which it rests. Its size is usually 3 in, or 4 in. square and of the required length. It is intended to resist the outward thrust of the hip rafter on the wall. In older methods an angle tie, commonly known as dragon beam was used. Fig. 461.

(vii) *Eaves*—The lower edges of the sloping surface of a roof are termed as the eaves. Gutters are usually fixed along the eaves to collect and drain the rain water. A timber plank usually measuring 6″ × 1″, is fixed along the eaves to cover the ends of common rafters. This piece is called eaves board.

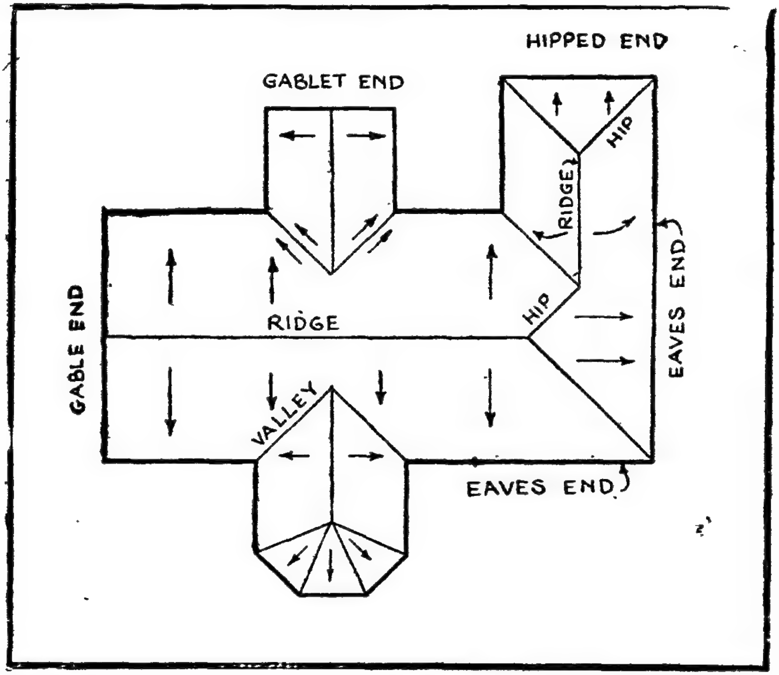


Fig 462. General plan of a pitched roof showing the various terms used

(viii) *Barge Boards*—Wooden boards used to fix the ends of common rafters projecting beyond the sloping top of a gable wall are termed as barge boards. Their size is usually 1″ × 7″ to 9″.

Art. 180. Common Terms used in Roof Construction.

(*Contd*)-(ix) *Purlins*—These are members either of wood or of steell, laid horizontally to support common raters.

They are supported by gable walls, roof trusses, hip or valley pieces as shown in Fig. 161 by *PP*. Their size is usually 5″ × 3″ to 6″ × 4″ depending on their spacing along the slope of the roof and their span. See Table XIII below. If boarding is placed directly on the Purlins, their spacing is nearer and the common rafters are eliminated.

TABLE NO. XIII

Minimum Size of Timber Purlins

Span in feet	Distance apart not exceeding		
	6 ft.	7 ft. 6 ins.	9 ft.
	ins. ins.	ins. ins.	ins. ins.
6	3 × 5	3 × 5	3 × 6
8	3 × 6	3 × 7	4 × 7
10	4 × 7	4 × 8	5 × 8
12	4 × 9	$4\frac{1}{2}$ × 9	5 × 9
14	5 × 9	$4\frac{1}{2}$ × 10	$5\frac{1}{2}$ × 10
16	5 × 11	5 × 11	6 × 11

(x) *Purlin Cleats*—These are blocks of timber or steel placed on the trusses to support the purlins. They afford direct support to the purlins and prevent them from sliding down. They are therefore fixed to the principle rafters of a truss. It may be noted that the purlins are sometimes notched if they are of wood, to rest on the principle rafters of a truss. This gives better lateral rigidity to trusses.

(xi) *Battens*—These are strips of wood usually varying from 1″ × $\frac{3}{4}$″ to $1\frac{1}{2}$″ × 1″. They rest directly on rafters or on ceiling, and are fixed to them by nails. The roofing tiles are laid directly over them.

(xii) *Wall Plates*—Common rafters are fixed to continuous pieces of wood, called, wall plates, at points where they rest on walls. Wall plates are embedded in masonry on top of walls nearly at the centre of their thickness. The

joint between the common rafters and the wall plates is formed by simple notching and nails are used to fix the two. The wall plates are lengthened by bevel-halved joint. The usual siez of a wall plate is 4" × 3", and is laid with 4-in side horizontal.

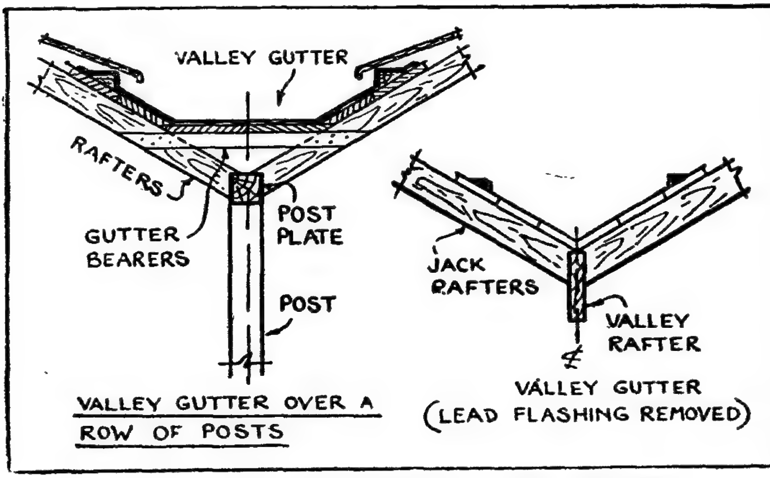


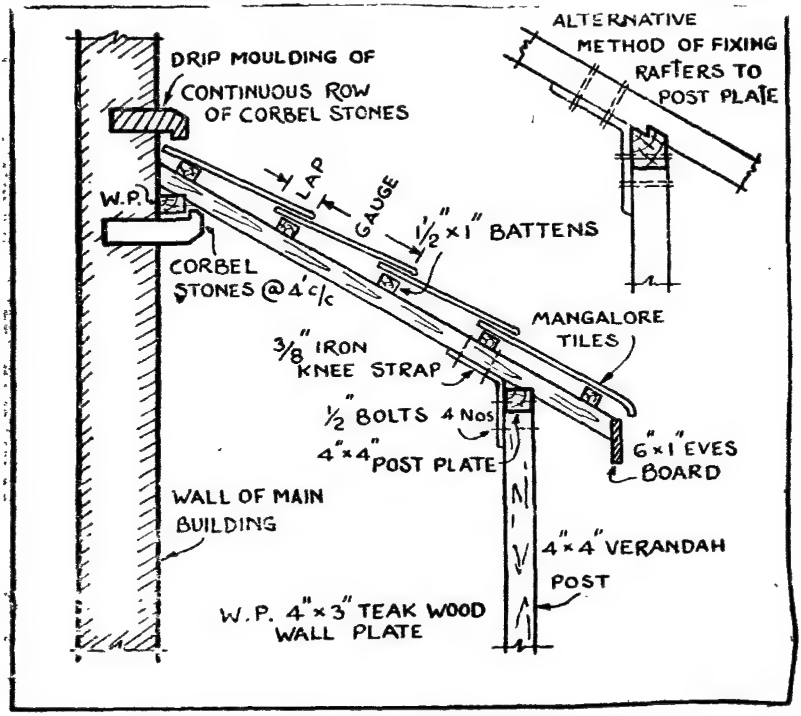
Fig. 463 snd 464. Getails of valley gutter contruction

(xiii) *Valley Gutter.* Along the valley line of a roof proper arrangements should be made to drain away the rain water by providing a valley gutter as shown in Figs. 463 and 464.

(xiv) *Poleplates*—At the tops of posts is laid a continuous timber piece to support the common rafters and at the same time to strengthen the ends of posts. These are usually of 4" × 3" size for ordinary spans. Special method of construction should be adopted to fix the common rafters to the post plate and the latter to the posts. Usuall a knee strap with bolts is provided for as explained later.

(xv) *Trimming*—Where a Chimney Stack paojects beyond a roof the rafters have to be trimmed. The usual construction details are the same as those given in Art. 128 so that a complete frame-work is made to secure strength and

rigdity. But in the case of trimming for chimney stack proper precautions must be taken to prevent leakage, at these points by providing boarding and zinc or lead gutter all round. Similar trimming is also necessary around the sky lights.



Figs. 465 and 463. Details of lean-to roofs.

Art. 181 Structural Aspects—Roofs may be classified into three main divions,—

(i) Single Roofs;

(ii) Double Roofs; and

(iii) Trussed Roofs.

As in the case of floors, structurally roofs also consist of two parts, one part consisting of supporing members which are common rafters, purlins, and trusses, either of steel or of wood, and the other part consisting of roof

covering materials which are either proprietory materials such as aspualt products, or rubber preparations, special felt, or clay tiles, metal sheets, slates, thatch, etc. The method of roof construction is almost the same as floors since the supporting members are erected first and then the covering materials are fixed on top of them. In this chapter the supporting structures of roofs are only considered. The problem of roof coverings is dealt with later.

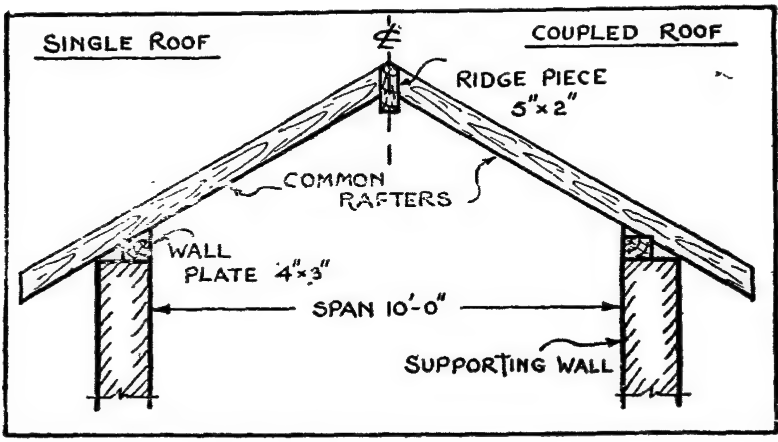


Fig. 467. Couple roof details.

Art. 182. Single Roofs—These include lean-to roof, couple roof, couple-close roof. and collar roof. They are of a simple design and are essentially formed by common rafters as supporting members, over which is placed a roof covering material of a suitable type.

Art. 183. Lean-to Roof—Fig. 465. These are formed with one slope only and are commonly used for out buidings, for verandahs and for sheds leaning against high walls of a main building. In the last case propor precautions shonld be taken to prevent leakage at the junction of thc lean-to roof and the wall, and for fixing the same to the main wall. In Fig. 466, the method of securing rafters to post plates is shown. This adds to the rigidity

of the roof in general. Spans upto 8 feet could be conveniently covered by this type of roof.

Art. 184. Couple Roof—See Fig. 467. These include roofs with slopes on either side of a central ridge. The rafters are fixed at their lower ends to wall plates embedded in masonry, and at their upper ends to a common

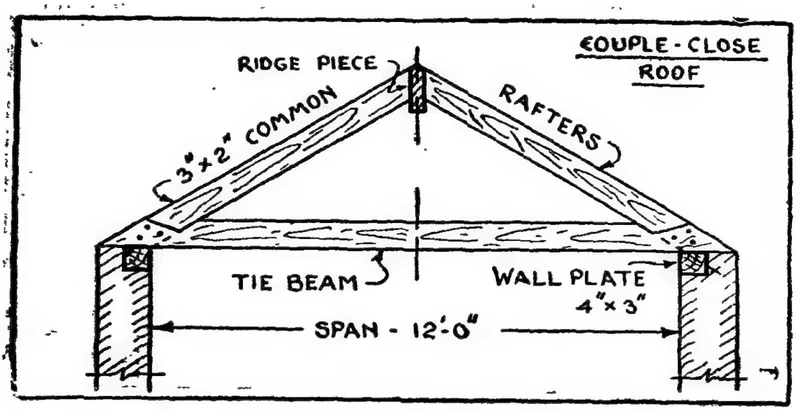


Fig. 468. Couple close roof with timber tie beam.

ridge piece. Couple roofs are usually limited to spans of 12 feet, though couple close roofs detailed below, are employed to spans upto 16'-0". For spans above 14 feet and upto 16 feet, it is preferable to use trusses and purlins as described later.

Art. 185. Couple Close Roof—Couple roofs exert an outward thrust on the walls. This thrust becomes great as the span of the roof increases so that, a tie is used to fix the rafter at their feet. This prevents the outward thrust from coming on the supporting walls. The tie may be a piece of wood or a steel rod in tension. See Fig. 468. The fram work of common rafters and tie beam thus formed rests on the wall plates as soown iu the above figure. For spans greater than from 10 to 12 feet, larger sections have to be used for rafters and ties which consequently become heavy and uneconomical Thus to prevent tne rafters from bending in the middle, the

tie may be placed half-way up the rafters, This type of roof is called the callar roof. It should be noted that the collar becomes a strut and hence is in compression.

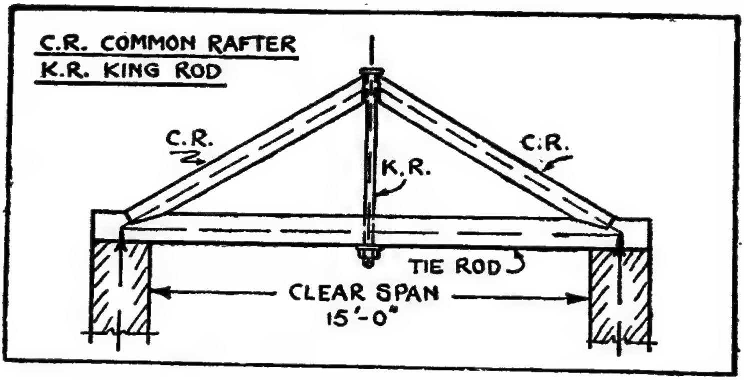
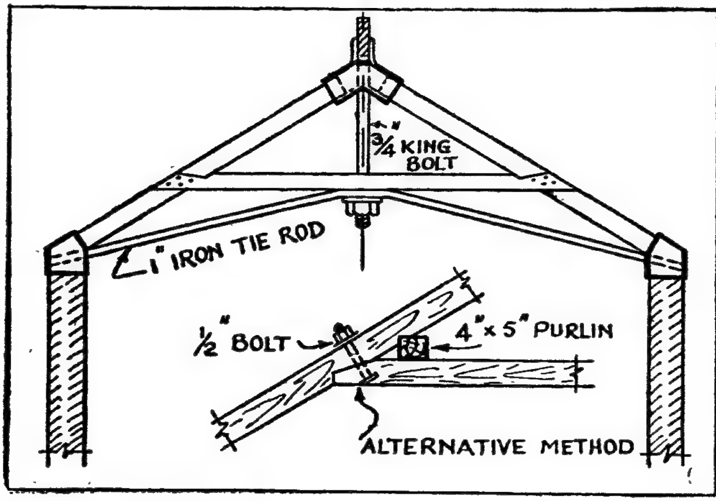


Fig. 469. Couple-close roof with a king rod.

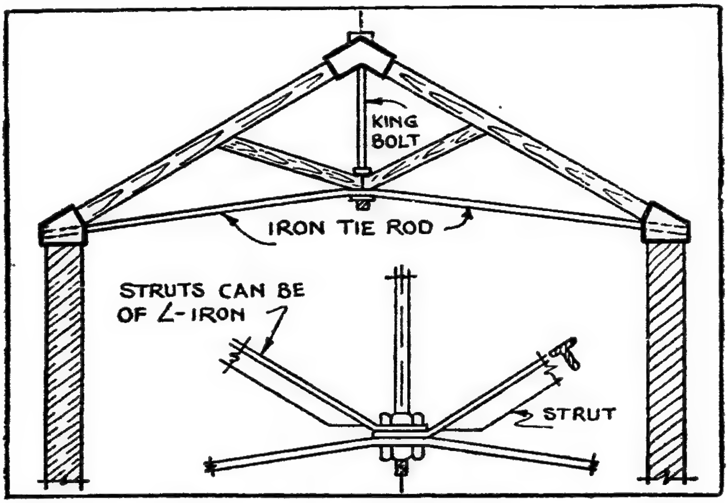
Similarly in the case of a couple close roof, the tie becomes very heavy for larger spans, and hence it is also



Figs. 471. Collar-berms roofs.

supported by a central king rod suspended from the ridge. Such an arrangement of various members is shown in Fig. 469. Couple roofs are used for spans upto 16 feet.

In Fig. 470 is shown a collar--beam roof with a steel king rod and steel tie rod. This is a modified form of a couple-elose roof and gives a very satisfactory arrangement for bigger spans. An alternate method of fixing the



Figs, 472 and 473. Type design oi a truss roof.

collar beam common rafter and the purlin is also shown in Fig. 471. In the type of roof shown in Figs. 472 and 473, the collar beam is repaced by two inclined struts.

Art. 186. Double Lean-to or Y-Roof-Somtimes the two slopes of a couple roof are brought inward to form a common valley instead of a riduge. The sloping ends are made to rest on a common timber piece which is supported by either a column or a wall. But such roofs involve great difficulty and extra cost of making a water-tight gutter in the valley.

Art. 187. Double Roofs or Purlin Roofs—It has been already remarked that when the span of a rafter exceeds 7 to 8 feet their size becomes uneconomical and heavy. Therefore horizontal cross pieces called purlins are introduced (refer Art. 171 ix) to reduce the span of the rafters

and to support them at intermediate points. See Fig. 474. They also stiffen the rafters and the roof as a whole. Usually 3″ × 2″ is a very convenient size for a rafter and could be safely used for spans upto 6 feet, and hence the span of a rafter should be kept down to this value as far as possible.

Art. 188. Illustrativ Problem—Calculate the size of a timber purlin T. P. shown in Fig. 474. The common rafters C. R. spaced at 18 ins. c/c rest on the purlin which is placed centrally between the ridge and the wall plate. Span of the purlin is 8'–0″ to centers of supporting trusses. Distance of the ridge from the wall plate is 13'–0″.

Solution—

(i) *Loads*—From the figure it is clear that the common rafters receive the roof load and transfer it to the purlin As the rafters are closed to each other, this load will be treated as distributed load on the purlin. The roof area supported by the purlin is shown by a cross in the figure.

Roof load per sq. ft. of sloping area:—

Dead loads—

Clay tiles	15 lbs./sq. ft.
Tiling battens $1\frac{1}{2}'' \times 1''$ ...	2 ,, ,,
$\frac{1}{2}''$ ceiling board	3 ,, ,,
Total dead load ...	20 lbs./sq. ft.
Incidental *live load* due to wind and workmen ...	30 lbs./sq. ft.
Total load ...	50 lbs./sq. ft.

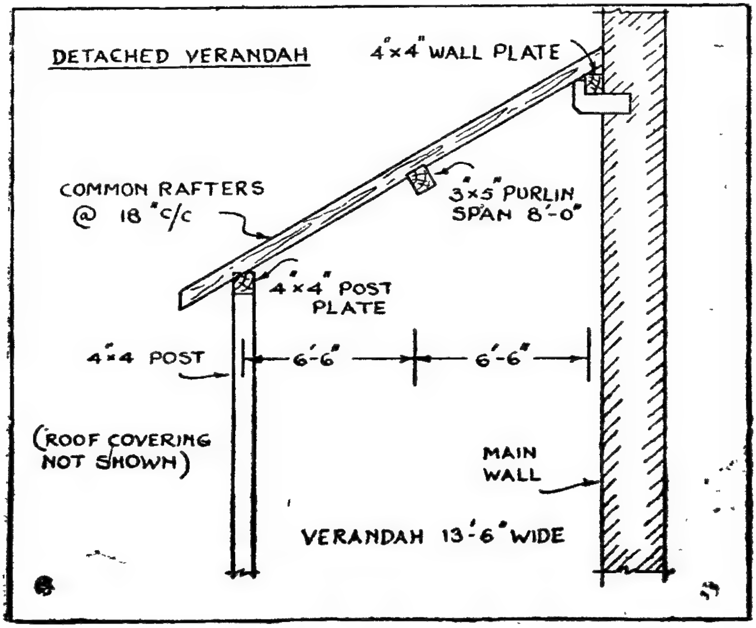
Roof Area—The slope of the roof is $1\frac{1}{2}$ horizontal to 1 vertical; or the rise is one--third span. This is the common slope used for tiled roofs and the equivalent length of the slope is 1.2 times the horizontal length approx.

∴ The roof area supported by the purlin equals,—

$8'\text{-}0'' \times 6'\text{-}6'' \times 1.2 = 31.2$ sq. ft.

Total load on purlin

$$= 31.2 \times 50 = 1560 \text{ lbs.}$$
$$= \tfrac{1}{8} \times 1560 = 195 \text{ lbs./r. ft.}$$



Figs. 474. Details of a Verandah roof.

(ii) *Bending Moment and size of purlin*—

$$\text{B. M.} = 195 \times 1.5 \times 8 = 18{,}700 \text{ in. lbs.}$$

$$\text{Section modulus} = \frac{18700}{1000} = 18.7 \text{ in.}^3$$

$$\text{or,} \quad bd^2 = 6 \times 18.7 = 11{,}2 \text{ in}^3.$$

Assuming a width of 4", for the purlin, we have, the depth of the purlin given by. *Adoptd size of purlin* 4" × 5".

If stress = 1250 lbs/sq. in; then size of purlin equals 3" × 4½" which is common size.

Note—Section should be tested for deflection and shear.

Art. 189. Trussed Roofs—We have seen that for greater spans rafters require intermediate supports in the' form of struts to reduce their size and to increase their rigidity and that the beams require the rods suspended from the ridge

to prevent it from sagging. These conditions are satisfied by building up frame works of timber called *trusses*. In addition, trusses have the advantage of transmitting roof loads in a vertical direction upon the walls. Triagular shape of a frame offers greater regidity preferably the triangle should be equiangular. This requires the trusses to be triangulated.

The second advatage of a truss is that each member is subjected to direct stresses either compression or tension. This is possible by applying the loads at the apices of the triangles; as othrwise the members would be subjected to bending stresses in addition to direct stresses. A proper guide to ensure this is to set out the truss frames by drawing the centre lines of all the principle members and to see that at the point of intersection of these lines at the joints, they meet in a common point. At the supports where the trusses rest on a wall or a pillar, the intersection of the centre lines of the beem and the principal rafter and the centre line of the bearing lie within the middle third of the wall.

The component parts of trusses are, principal rafters, tie beam, ties and struts. These parts are framed together on the principles mentioned above. The roof load is tarnsmitted to the trusses through purlins and ridge which should be preferably placed so that every member is in direct tension or compression. The purlins in their turn support the common rafters or the boarding which carry the roofing materials.

The spacing between the trusses is usually kept between 8'–0" and 10'–0". While designing a roof truss it is economical to arrange the panels of principal rafters of lengths not exceeding 6' – 0" or so, since this becomes the span for the common rafters whose economical size under common loads is 3" × 2" for timber, as previously pointed out.

Art. 190. Details of King Post Truss—In Fig. 475 is illustrated a king post roof truss for sixteen feet span. Both the methods of forming the ends of roofs are shown in the figure; in the one ease the roof ends against a parapet and

in the other case an eaves gutter is formed. While framing the various members of the truss, precautions should be taken for jointing. The various joints should be strong and rigid. These are described below.

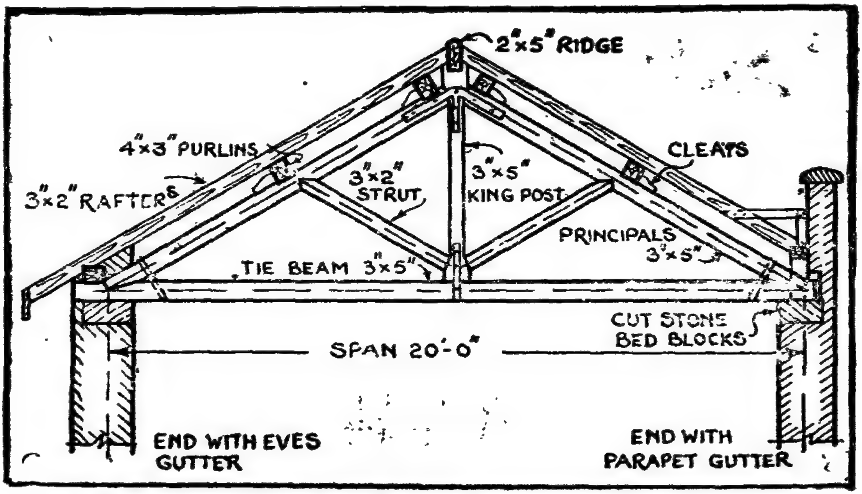


Fig. 475. King post truss with the principal supporting members of a roof.

(i) *Tie Beam and Principal Rafter*—The joint between these two members should be sufficiently strong to prevent the principal rafter from spreading out. The bottom of the principal rafter is jointed to one end of the tie beam by the simple abutment and tenon joints. See Fig. 476. An inclined wrought iron heal strap is also fixed round the principle rafter and the two ends of strap are held in position by a bolt passing through the tie beam. Alternatively, the method shown in the above figure is also suitable.

(ii) *Tie Beam and King Post*—The king post is formed with splayed shoulders and feet to receive the principal rafters and the struts respectively. See Fig. 477. At its lower end it carries a tenon which fits into the mortise at the centre of the tie beam. A stirrup strap is fitted at the joint and at the upper end of the stirrup strap gibs and cotters are driven. The arrangement is shown in detail in Fig. 478. The tie beam is

usually given a camber of 1 in 30 to prevent the unsightly appearance due to any settlement.

(iii) *The Struts and the King Post* are jointed by an oblique mortise and tenon joint, the strut fitting in the

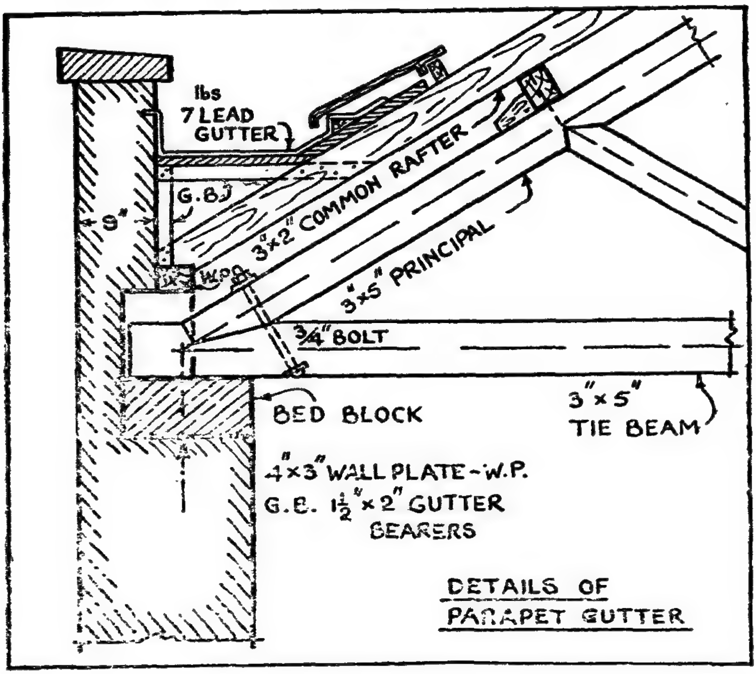


Fig. 476. Details of parapet gutter and joint at the foot of truss.

widened feet of the king post. For fixing the struts with the principal rafter oblique mortise and tenon joint with single abutment is used to prevent the strut from sliding down See Fig. 476.

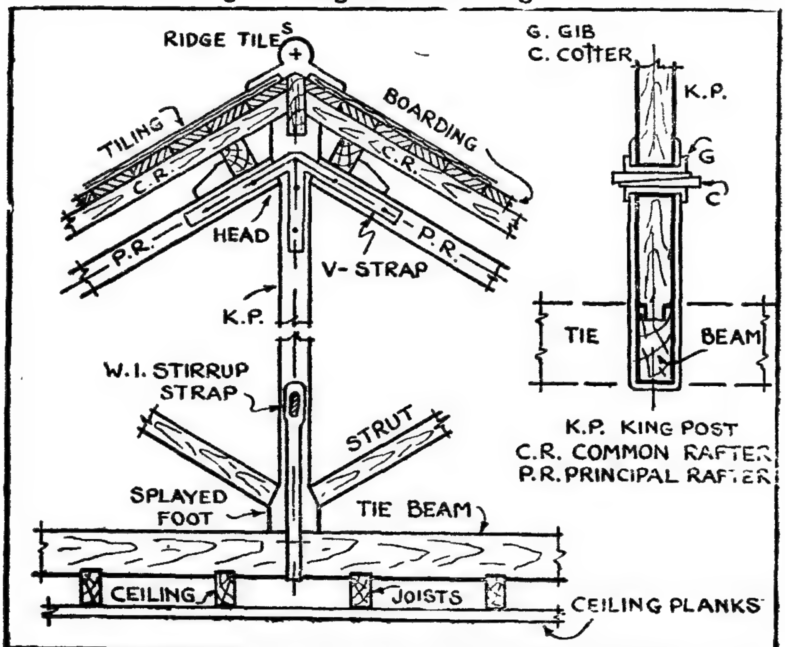
(iv) *Head of Principal Rafter and King Post*–The two upper ends of the principal rafters are fitted into the widened shoulders of the king post and a V—shaped or a three-way iron strap is attached by means of bolts to the three members meeting at the joint, as shown in the above figure.

TABLE NO. XII

Size of Various Members of Teak Wood Trusses at 10 Feet apart. Mangalore Tile Roof 15 Lbs/sq. Ft. Wind Pressure 20 Lb./sq. Ft. Slope 30 Degrees.

	Tie-beam				Principal				King post or Queen post				Struts				Straining-Beam				Straining Sill				
Span ft.	Length	Breadth	Depth	Contents	Length	Breadth	Depth	Contents	Length	Breadth	Depth	Contents	Length	Breadth	Depth	Contents	Length	Breadth	Depth	Contents	Length	Breadth	Depth	Contents	Contents of truss
	ft.	in.	in.	c. ft.	ft.	in.	in.	c. ft.	ft.	in.	in.	c. ft.	ft.	in.	in.	c. ft.	ft.	in.	in.	c. ft.	ft.	in.	in.	c. ft.	c. ft.
12	15	3	3	0.95	7	3	4	1.20	4	3	5	0-45	3½	3	2	0.29									2.89
14	17	3	3	1.00	9	3	4	1.65	5	3	5	0.55	4	3	2	0.35									3.45
16	19	3	3	1.20	10	3	4	1.65	5½	3	5	0.60	4½	3	2	0.39									3.84
18	21	3	4	1.75	11	3	4	2.40	6	3	5	0.67	5	3	2	0.44									5.25
20	23	3	4	1.95	12	3	5	2.60	7	3	5	0.75	6	3	2	0.50									5.75
22	25	3	4	2.10	14	5	5	2.90	7	3	5	0.80	6½	3	2½	0.67									6.44
24	27	3	4	2.25	15	3	5	3.20	8	3	5	0.85	7	3	2½	1.21									7.00
									Queen Post Truss																
35	13½	4	5	5.62	14½	4	7	5.64	7½	4	5	2.08	7	4	3	1.21	12½	4	5	1.73	12½	4	2	0.69	16.97
40	15	5	5	7.78	16	5	7	7.78	8	5	6	3.44	8	4	3	1.33	14	5	6	2.97	14	5	2	0.98	24.31

(v) The head of the king post is slotted to receive the ridge piece. As usual the common rafters supporting the roof covering abut against this ridge from both sides.



Figs. 477 and 478 Details ot the joint at the ridge and at the foot of the king post.

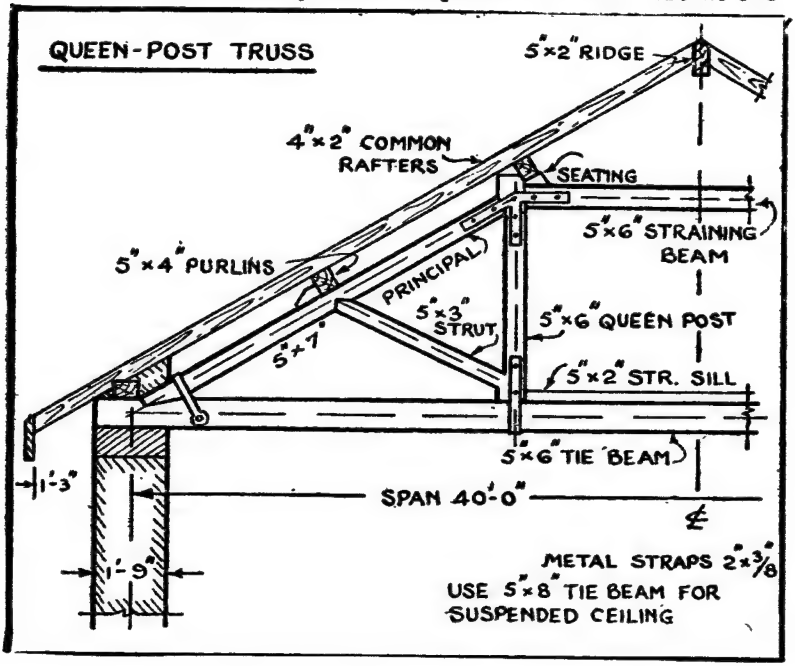
King post trusses are used economically for spans upto 20 feet. For spans bigger than 20 feet and upto 40 feet a queen post truss is more suitable. In Table No. XII are given the sizes commonly used for the various members of king and queen post trusses for different spans.

Art. 191. Methods of Supporting Roof Covering— Purlins, common rafters, boarding and battens are placed on the trusses and across and along the slope of the roof as required. As previously explained purlins should be placed at the panel points of a trusses. They serve two purposes.

(i) They tie the trusses together and afford ridigity to the roof.

(ii) They carry the common rafters and reduce their span to a common economic value of 6 to 8 feet.

To satisfy the requirement of load transmission in truss members, it is necessary that the purlins should rest at the



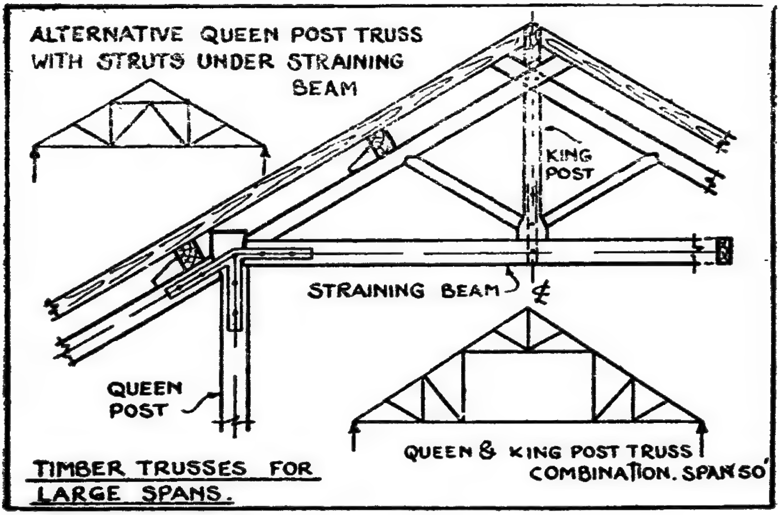
Figs. 479. Detail of a queen post truss and the method of fixing purlins and common rafters.

panel points on the principal rafters. Under their seat there is a slight cogging made on the back of the principal rafter. Cleats are also employed as shown in the figure to give the necessary lateral support to the purlins. In some forms of construction the boarding rests directly on the purlin without the common rafters.

In such cases it is not always possible to place the purlins at the panel points.

Thus we have two distinct methods of supporting the roof on the trusses.

(i) *Common rafter construction*—where purlins are placed at the panel points of the truss and the common rafers are placed over them. The boarding may or may not be used on the common rafters.



Figs. 480, 481 and 482. Timber trusses for large spans,

(ii) *Purlin rafter construction*—Where the purlins are placed on the principle rafters of a truss at a spacing, of about 4′ – 0″ to support the boarding directly. In this case the purlins also rest at intermediate points other than panel points and · the common rafters are eliminated.

Art. 192. Bed Blocks—The loads at the ends of trusses are of a concentrated nature. This requires the trusses to be placed on bed block as in the case of beams and girders of floors. See Art. 124. The bed blocks should be preferably for the full width of the wall. In the above figure of a king post roof truss cut stone bed blocks are shown for the ends of the truss to rest on and to distribute the load on the wall uniformly.

Art. 193 Queen Post Truss—The details of a queen post truss for a span of 40 feet is shown in elevation in

Fig. 479. The king-post of the king-post truss is replaced by two queen-posts having single splayed shoulders at the

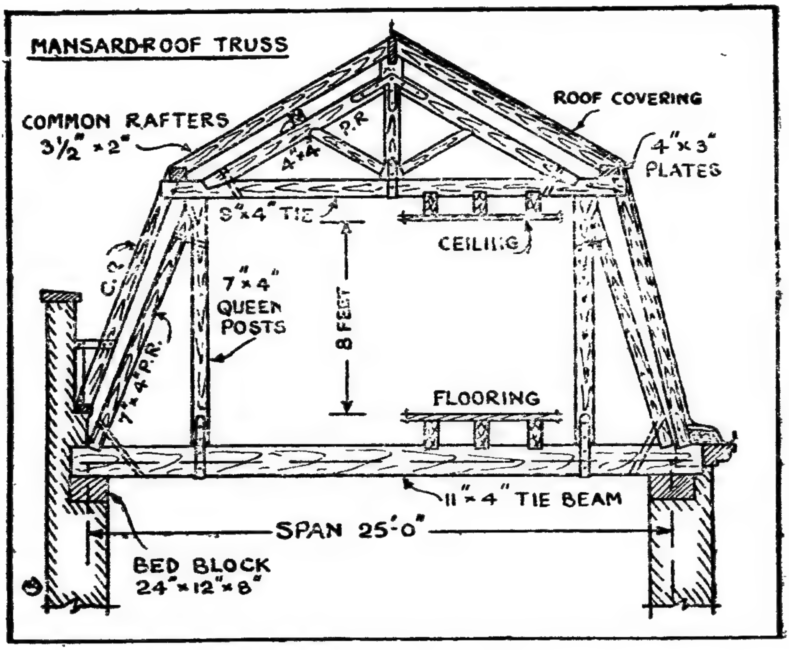


Fig. 483. Mansard roof truss.

foot and at the head. The tie beam and the principles are jointed to the queen-post like the king-post by using the metal straps. The heads of the queen-post are connected by a straining beam to prevent their leaning towards the inside. The principals usually end at the heads of the queen-post, in which case the above straining beam is very important to give rigidity to the truss. When the principals do not extend byond the heads of the queen-post, only the common rafters of a smaller size are carried upto the ridge. Again when the tie beam of a whole length is not availble a joint is introduced in the middle. Between the feet of the queen-post and on top of the tie beam, a straining sill is fixed to resist compression.

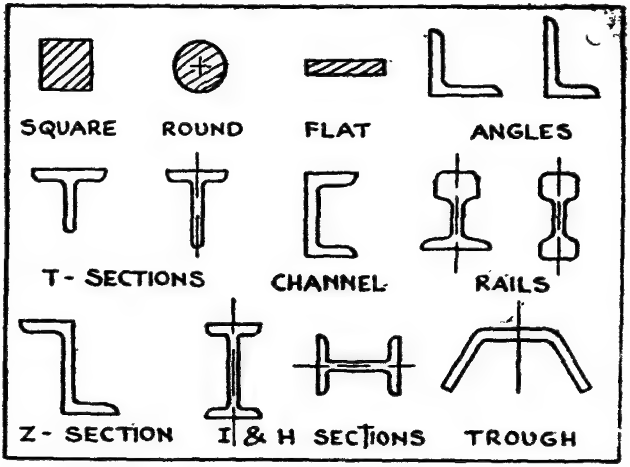
Queen-post Truss is usually suited for spans upto 40 feet. For greater spans a combination of queen and king-post trusses can be adopted. Such trusses are shown in Figs. 480 to 482. The line diagrams are for greater spans; but commonly this type of combination truss is suited for spans upto 50 feet.

Art. 194. Mansard Roof Truss—A type of mansard roof truss is shown in Fig. 483. The truss has two different slopes, the one in the lower position being very steep. It is in fact, a combination of two trusses,—the king-post and the queen-post trusses—, except that the lower queen-post truss has its two queen-posts shifted near the ends of the tie beam, This has an effect in increasing the steepness of the end stopes. This roof is often used to utilise the cubic space under a truss for living purpose, while the general height of the toof is kept compartively low.

CHAPTER XV

Structural Steel Work

Amongst the various materials used in construction works cast iron, wrought iron, and steel are very common.

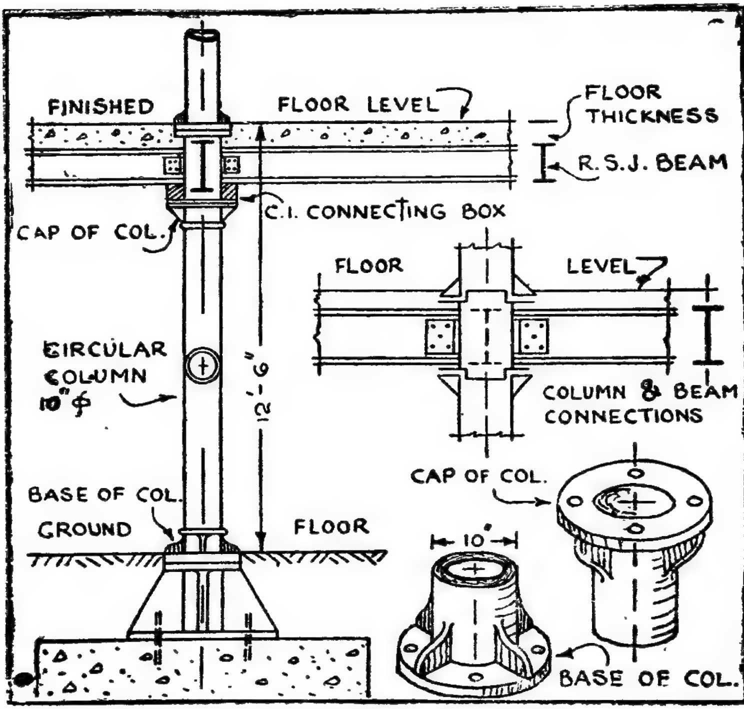


Figs. 484 to 497. Various forms of rolled steel sections.

These materials possess different structural properties due to the different amounts of carbon contained by them. Of these three metals steel is the most commonly used one. It is available in the market in various forms as given in Figs. from 484 to 497. The design of any particular section to be used having been decided, the method of using them actually in the construction of structures will be given in the following articles. As a manufactured article steel sections are tested for their structural properties before they are used. Each section is specified by its size and weight in pounds per foot run.

Art. 195. Cast Iorn and Steel Columns—Columns are members resiting compressive stresses in the direction of their

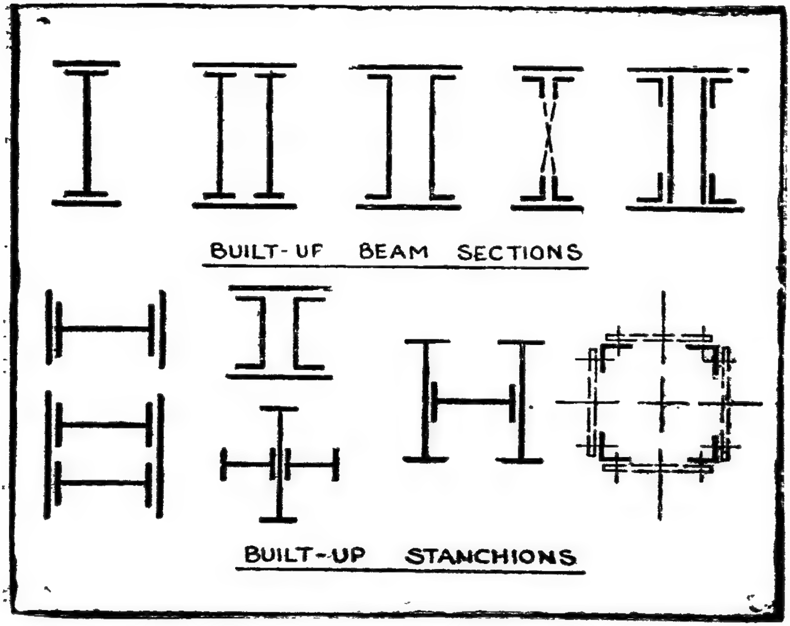
length. Sometimes they have to withstand bending stresses also. Normally they are square or circular in section and are either solid or hollow. Cast iron columns are circular whereas steel columns may be rolled steel sections or built up sections of two or more rolled steel sections. In the latter case they are termed as stanchions.



Figs. 498 and 499. Details of cast iron column and beam connections. Figs. 500 and 501. Cast iron column base and cap.

Cast Iron Columns—A typical cast iron column with its various connections to support the beams is shown in Figs. 498 and 499. The base and the cap of the column are also shown in Figs. 500 and 501. Cast iron columns should not be less than 5" in diameter and if hollow the thickness of the metal should not be less than $\frac{3}{8}$". Their length should not exceed 18 to 20 times their diameter. The bases of these columns are provi-

ded with holes, and rest on concrete beds, the thickness and base area of which are sufficient to distribute the load on the soil below. Cast iron columns are very strong in compression. They are comparatively cheaper than those of steel.



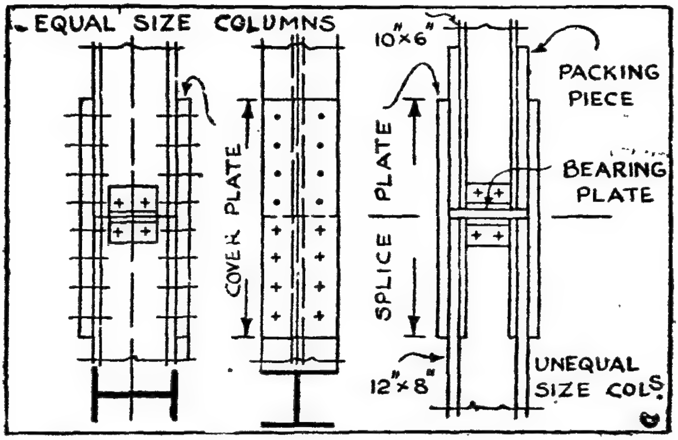
Figs. 502 to 512. Built up beam and stanchion sections.

They possess an attractive apperance, and corrode to a much lesser degree than steel columns. But there are possibilities for internal defects like air-bubbles, honeycomb castings, etc. to be present in them which seriously affect their strength. In addition cast iron columns tend to crack, if suddenly cooled by water after they are heated as in the case of a fire occuring in a building.

Art. 196. Steel Stanchions—To overcome the defects of cast iron columns mentioned at the end of the last article, columns are usually built of steel. These columns may be of a single rolled steel section or a built up section of two or more such rolled steel sections. The rolled steel sections which are

used as stanchions have a broader flange. Some of the built up stanchions are shown in Figs. 509 to 512.

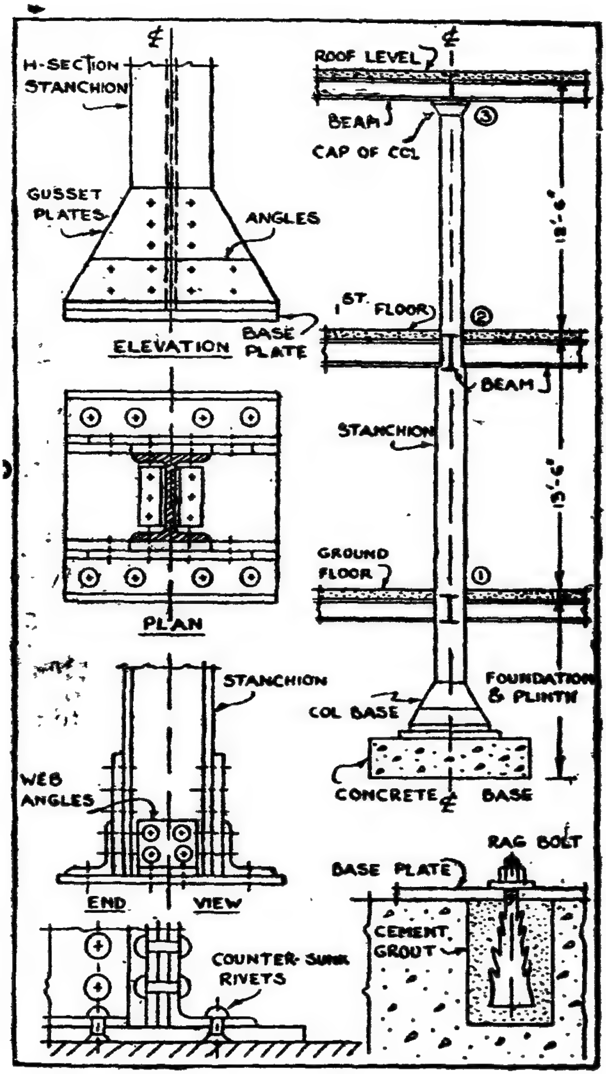
(*a*) *Longitudinal joints in Column*—Very often it is necessary to join two lengths of stanchions end to end, either



Figs. 513 to 515. Showing details of column splicing of eqeal and unequal sections.

due to a single length being not available or to reduce the section of stanchion in the upper storeys than that required for the lower storey. For this purpose cover plates called splice plates are used over the flanges and the webs of the stanchions as shown in Figs. 513 to 515. A bearing plate is inserted between the ends of a smaller depth extra plates known as packing pieces also have to be inserted.

(*b*) *Base Connection of Stanchions*—Stanchions have to be provided with specially built up bases as shown in Figs.516 to 519. In these Figs. are shown elevation, plan, end view and section of one column. Gusset plates are fixed on the sides of the stanchion to which are again fixed base angles on the outer sides. Additional base angles can also be fixed to the web of the stanchion. The stanchion rests on a base plate which is finally fixed to the rag-dolts, grouted with cement in a concrete.



Figs. 586 to 519. Elevation, plan, end view and section of base connections of a stanchion.

Figs. 529. Details of connections of base plate, rag bolts and concrete bas

Fig. 521. Stanchion datail of a two storied building with connecting floors

base. See Fig. 251. A complete sectional elevation of the stanchion in a two storeyed building supporting the R. S. beams and floors is shown in Fig. 521. In the foundation and plinth section of the stanchion are shown its base connections and the concrete base.

Art. 197. Beams. Joists and Stanchion Connections— Steel beams may be either R. S. joists or built-up sections. The various types of built-up beam sections are shown in Figs. 502. Beams are conneted to stanchions with the aid of angle iron cleats to the flanges and webs as shown in Fig. 522. Single rivetted joints or double rivetted joints may be used as required. Similarly R. S, joists are also connected to the web of main girders with the aid of angle iron cleats and rivets.

Art. 198. Erection of Struturl Steel work—This has got to be carried out very cautiously. Stanchions are erected with the aid of a derrick pole of the required height to which are attached pulley tackles. The lifting end of the rope passing through these pulley tackles is tied round the stanchion aprroximately at its centre, which is then gradually raised and placed vertically in its position. To control the movements of stanchion thus lifted guide ropes are tied at its lower end.

Heavy beams are raised and finally qlaced in positon in a similar manner with the aid of one or two derrick poles. On large construction works cranes of various capacities are installed to lift and place in their position the respective stanchions, beams, and roof trusses.

Art. 199. Steel Roof Trusses—For greater spans timber trusses become heavy and it becomes economical to use steel trusses. Usually for spans greater than 25′ to 30′ steel trusses are recommended. Apart from lightness, steel trusses have the advantage of durability due to their immunity from attack of white ants, dry rot and greater fire resisting property. They are easy to build and very convenient to transport to

site. The usual types of trusses for various spans are shown in Figs. from 523 to 534.

While designing a trussed roof care should be taken to see that each member is either in direct compression or in direct tension as stated in Art. 180 under timber trusses. But sometimes, as in the case of smaller roofs the purlins are often

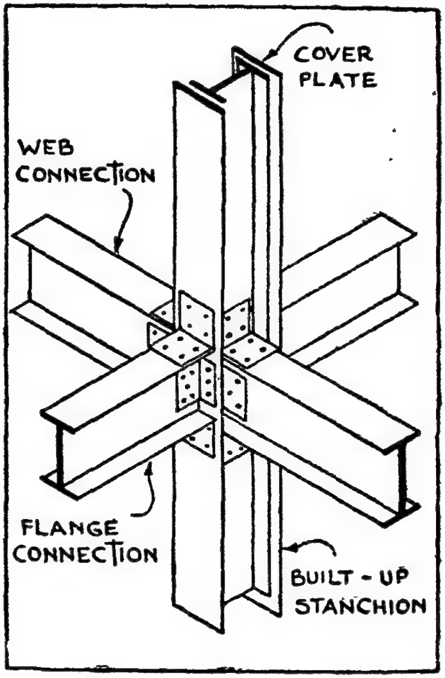
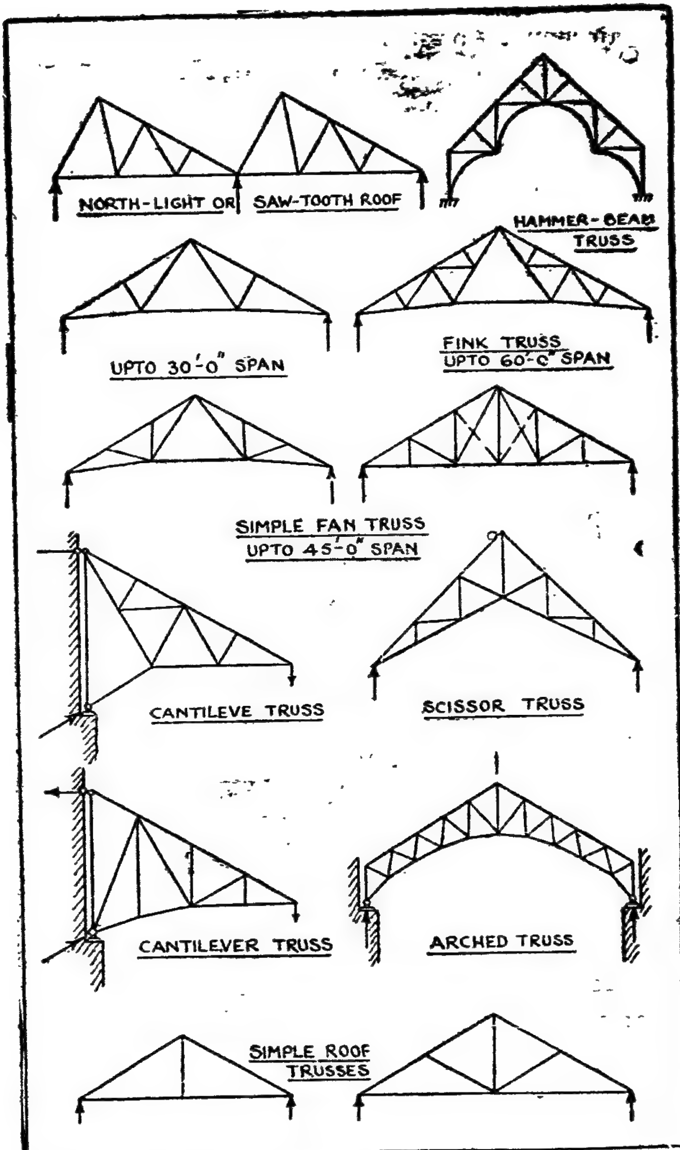


Fig. 522. Beam and stanchion connections.

distributed along the length of the principal rafter and this induces transvrse stresses in the members. Similarly if a ceiling is suspend from the tie beam of a truss transverse stresses become unavoidable.

The spacing for the steel trusses is usually kept between 10 and 15 feet. For small trusses the ends are fixed. Due provision should be made for expansion and contraction in the case of large trusses. The usual method is to provide oblong



Figs 523 to 534. Different types of roof trusses.

slots in the base plates through which the truss is fixed to its supports. Another method of providing for expansion and contraction in the case of a big truss is to rest one of its ends on a chair mounted on steel rollers, the other end being fixed.

For series of trusses wind ties, diagonal braces between the two end trusses should be provided on either side to prevent the general distoration of the roof due to wind action

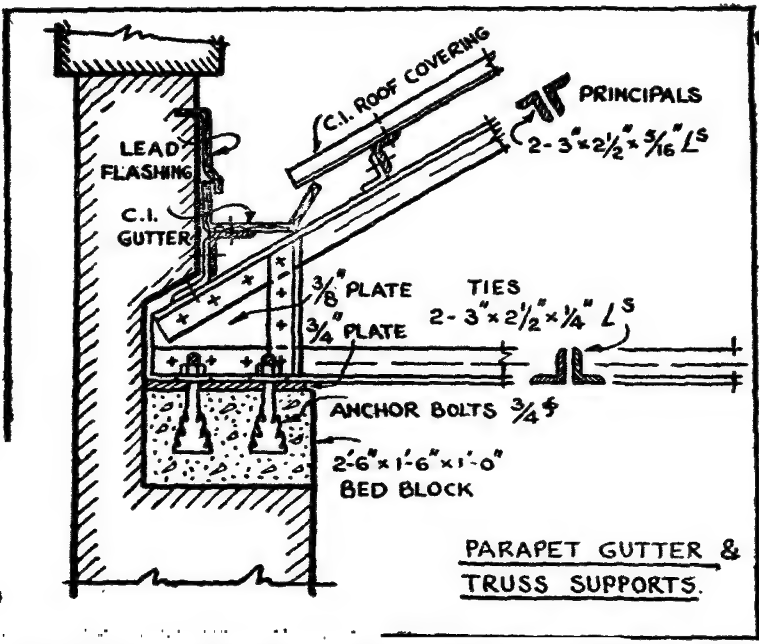


Fig. 535. Details of Steel truss and roof with parapet wall and gutter.

Art. 200. Joints in Steel Trusses—(*a*) *Rivited Joints*—The various members of a steel truss are jointed with the aid of gusset plates and rivets. If the truss is a very big one, to facilitate construction and transport, it is built up in two,parts which are subsequenly jointed with the aid of bolts.

(*b*) *Welded Joints*—Recently the art of welding has developed to a great extent and the various members of a truss are welded instead of being rivetted and bolted as mentioned above. The following are the advantages of welding:—

(i) As there are no rivet holes drilled in the member the entire cross sectional area of a tension member becomes available for taking the stresses.

(ii) Welding eliminates the noise of rivetting and in the cities this is an important advantage.

(iii) The process of rivetting is generally considered a laborious one, specially in intricate positions. The jointing

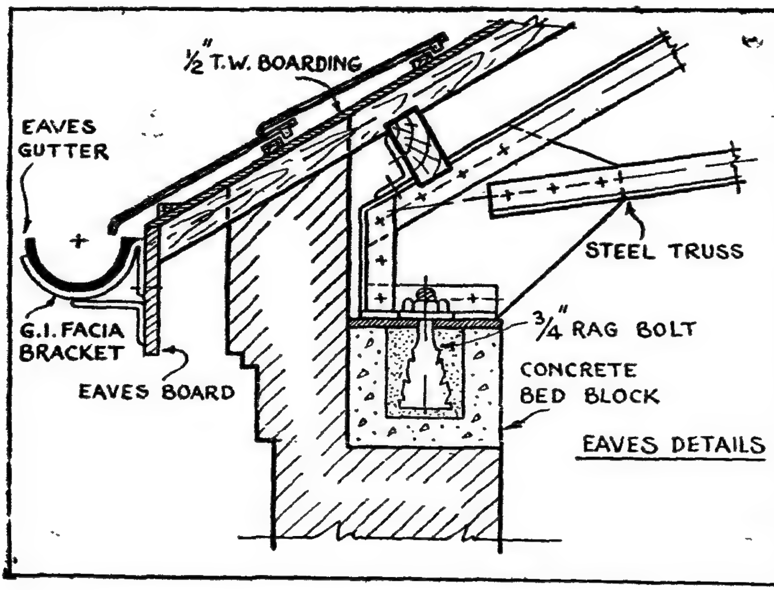


Fig. 536 Details of steel truss and roof with eaves.

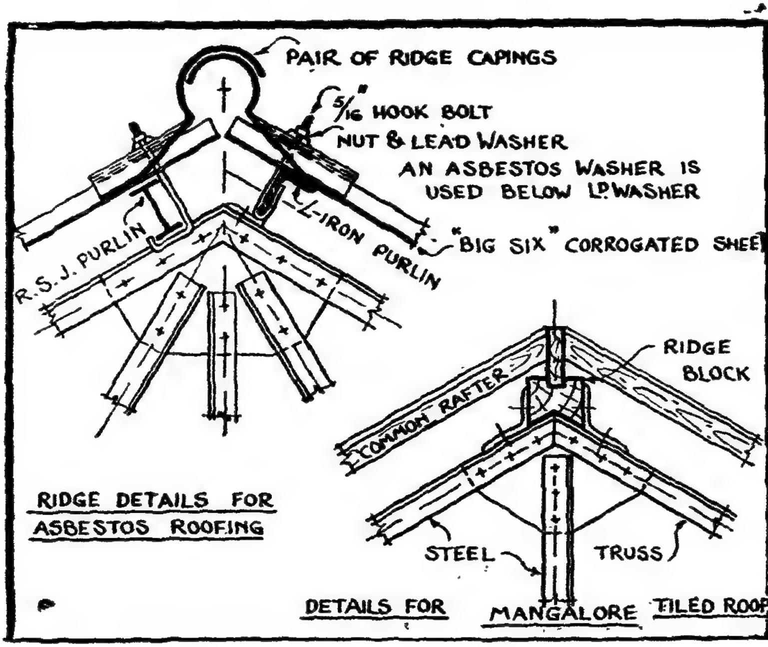
process by welding is comparatively an easy and a very convenient one.

(iv) Due to the elimination of angle cleats welding becomes cheaper for beams, joists, and stanchion connections, and thus work becomes economical on a large scale.

(v) Welding is associated with the rapidity of assemblage and erection.

Art. 201. Details of Steel Truss and Roof—In Fig. 532 are given the details of a steel truss roof with para-

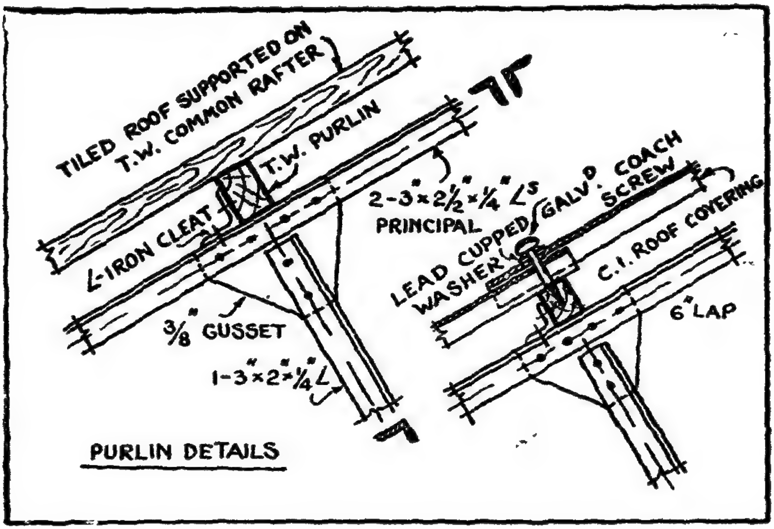
pet wall and gutter, and the method of fixing the truss to the supporting wall. The use of bed blocks, base plates, and anchor bolts is also shown. The drainage of the roof is carried out with the aid of a cast iron gutter supported on an angle iron runner fixed at the foot of the principal rafter. The necessary lead flashing by the side of parpet is also shown in the Figure.



FIFs. 537 and 538. Details of steel truss and roof at ridge.

In Fig. 536 the method of constructing the ends of roofs with eves gutter is shown. The roofing consists of common rafters, teak wood boarding, battens and Mangalore tiles as against metallic roof coverings of corrogated iron sheets. Teak wood purlins are used to span between the trusses and to support the common rafters. An eves gutter is provided to drain the roof and is supported on G. I. facia brackets fixed to eves board.

Art. 202. Details of Steel Truss and Roof (*Contd.*)— The details of the jointing required an the ridge are shown in Figs. 537 and 538. In Fig. 537 the roofing consists of corrogated sheet and a pair of ridge capings are provided at the ridge. The purlins may be either rolled steel joists or angle irons. The method of fixing the roofing materials to the purlin with the aid of hook bolts is also shown in the above Figure. In Fig. 536 a teak wood ridge block is fixed at the summit of the truss on which is placed the teak wood ridge. This allows the common rafters to be jointed at the ridge and a mangalore tile roof to be finally placed on the top.

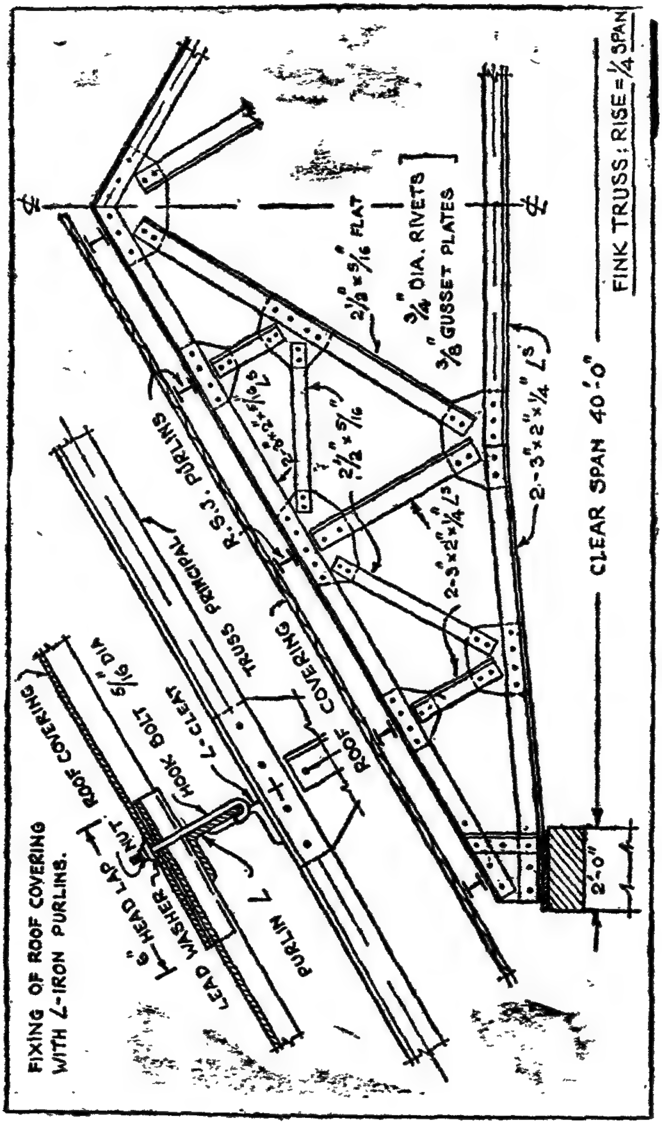


Figs. 539 & 540. Details of steel truss and roof at itnermediate joints.

In Figs. 539 and 540 intermediate joints for the two types of important roof coverings, viz. the Mangalore tile roof and the G. I. roof, are shown. It will be noticed that the purlins used in these cases are of teak wood supported on angle iron cleats.

The various details of the joints hitherto mentioned are shown in Fig. 541 which is the elevation of a steel truss

suitable for a span of 40′. The method of fixing roof covering with angle iron purlins is also shown in detail in Fig. 539,



Figs. 541 and 542. Details of a 40′-0″ span steel roof truss.

CHAPTER XVI

Temporary Carpentry

SCAFFOLDING, STAGING, SHORING AND UNDERPINNING.

Use and requirements of temporary carpentry. Scaffolding,—component parts. Brick layer's and mason's scaffolding. Ladder scaffolding. Chimney and spire scaffolds. Staging. Dome scaffolding. Needle scaffolds. Suspended scaffolding. Steel scaffolding.

Gantries—Travellers and platform.

Shoring and its varieties—raking, flying and dead shores. Underpinning.

Art. 203. Use and Design of Temporary Carpentry— For construction work timber is used into two principal catagories, viz- temporary and permanent carpentry work, as explained in chapter VII. In this chapter are given the various methods by which, during the construction of a structure, temporary carpentry work is employed for the following reasons, such as,—

(i) To render support to its various members, viz,—arches, lintels, etc.—*Centering.*

(ii) To render temporary support to the sides of excavation in loose and sandy soils for foundation work and for deep trenches for laying pipe and sewer lines, and also for preventing the settlement of neighbouring building,—Shoring and Strutting, and Timbering of excavation.

(iii) To facilitate the access of men and materials at higher levels to proceed with the oonstruction work,—

Scaffolding and staging platforms.

(iv) To execute repair and renewal work to unsafe structures by way of a temporary support—Raking, Flying and Dead shores.

(v) To provide temporary support for laying coucrete either plain or reinforced, until it gains strength.—Form work, Centering and Moulds.

In all the above cases, the temporary carpentry work should be properly designed to satisfy the various requirements. These are,—

(*a*) The temporary carpentry work should be strong, sound and rigid to meet the various structural requirements at places wherever it is used.

(*b*) Its design should permit of quick erection and easy removal without much damage to itself.

(*c*) It should admit of being used several times so as to minimise the cost spent on such temparary work.

(*d*) The timber used should be dry and well seasoned. The use of green timber is not permitted as it warps and cracks on drying and easily bends under loads.

(*e*) While securing connections between the various members of a temporary carpentry work, nails should be very sparingly used. For such purpose the use of bolts and pairs of wedges is always recommended.

It may be mentioned here that the term "Temporary" is used for the above type of carpentry work, only to indicate that after the construction work is completed, it does not remain permanently in position as in the case of permanent carpentry work. See Art. 91. In the previous chapters the method of providing shoring and strutting, centering and form work has been already explained and in the following pages are given the details of constructing scaffolding, shoring, underpinning and staging.

Scaffolding and Staging

Art. 204. Scaffoldig—The use of scaffolding in building operations as a temporary structure for supporting platforms for workmen, structural materials and appliances required during construction, is very common. A typical scaffolding as used for wall construction is shown in Figs. 543 and 544.

Compound Parts of a Scaffolding—These include (i) standards; (ii) ledgers; (iii) putlogs; (iv) diagonal braces; and (v) working platforms, toe boards and guard rails. The vertical standards which rest on the ground, are fixed at about 6 to 8 feet apart and are firmly connected

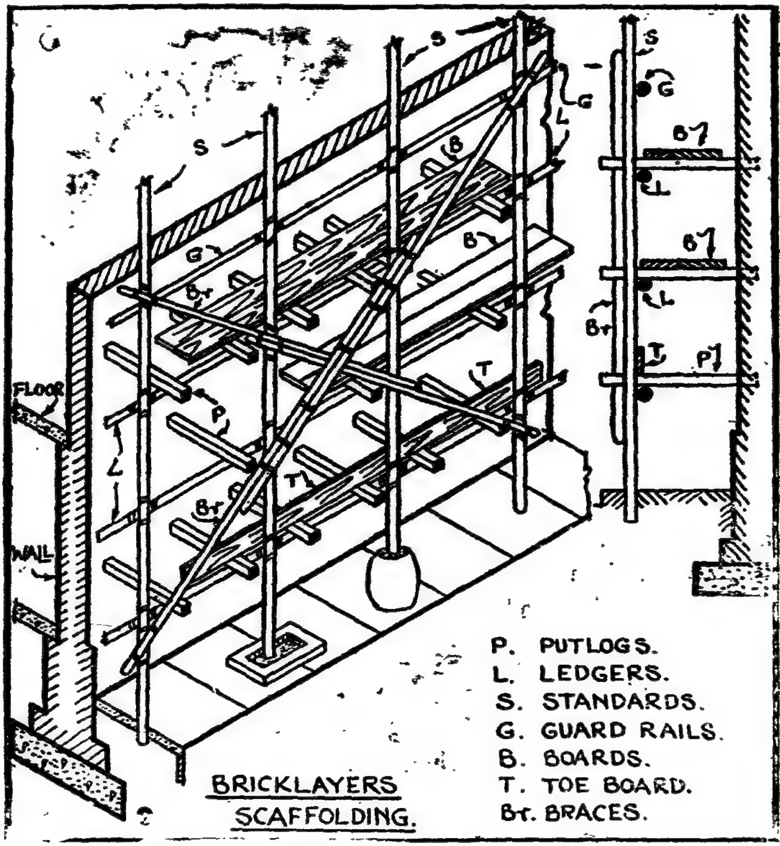


Fig 543. Details of brick layer's scaffolding.
Fig 544. Cross section of the above.

each other by horizontal ledgers placed at right angles and spaced at a vertial distance of 5 ft. 6 ins. apart. The standards and ledgers are securely lashed together by ropes. Cross timbers known as putlogs, spaced horizontally at 3 to 4 feet centers, are resting on the ledger and are intended to

support the planks forming the working platform. When the scaffolding is long and is designed to reach greater heights, cross or diagonal braces are fixed for stiffening and for preventing lateral movements. In addition, guard rails and toe boards are provided for protection at the level of the working platform.

Art. 205. Bricklayer's Scaffolding—The ordinary type of scaffolding, known as the bricklayer's scaffolding, consists of one row of upright poles or standards fixed along the wall and at a distance of about 6 to 8 feet apart as described above and are cannected horizontally by ledgers, and their other ends are placed in the holes left in the wall. As the construction or repair work is completed from the top of the stsucture, the putlogs are drawn out and the holes left in the wall are filled up.

This is a very cheap type of scaffolding. Usually the grip offered by the putlogs in the wall is not enough to prevent the scaffolding from building away form the wall. Thick ropes or wires are tied in addition to the standards, are passed through the wall to carry counter weights on the inside. Sometimes extra putlogs are passed through window openings and are tied to vertical poles on the inside.

Art. 206. Masons Scaffolding—Stone masonry buildings and structures where heavier materials of construction are used, a stronger scaffolding is required. This is provided by a double scaffolding, where two rows of standards are used, one, the inner row next to the wall and the other, outher row at a distance of 4 to 5 feet away from the wall. The putlogs rest entirely on the scaffoldiug ledgers. In addition to the diagonal braces, inclined supports called shoring have to be provided to prevent the scaffolding from leaning away from the wall. For a double scaffolding there is no necessity of leaving holes in the wall and it is completely independent of it. See Fig. 545.

Art. 207. Ladder Scaffolding—See Fig 546. Ladder scaffolding provides an improved method of a double scaffold-

ing, which could be easily assembled and taken down for light work such as exterior paintings and decorations. Several

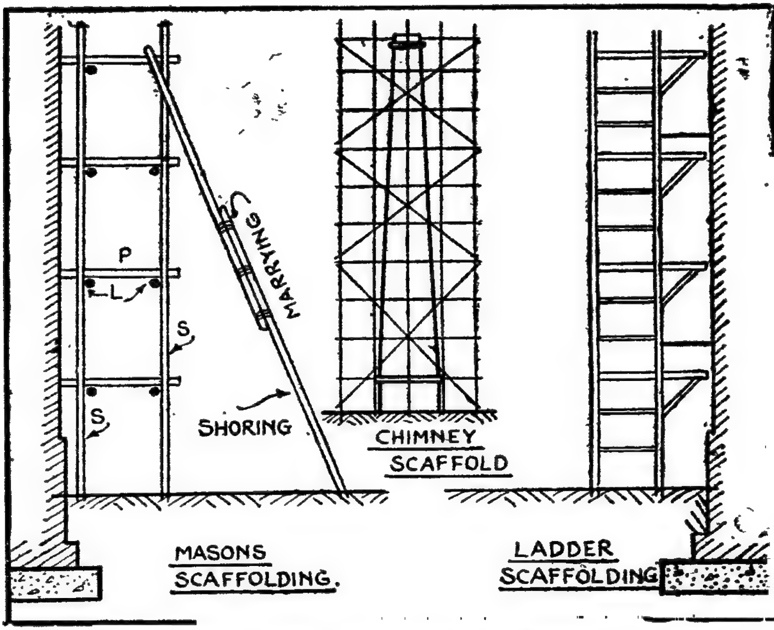


Fig. 545. Masons Scaffolding, shown in seciton with shoring.
Fig. 546. Chimney Scaffolding. exrernal type.
Fig. 547. Ladder Sraffolding showing platforms and ties.

patent ladder scaffolds are available where extension ladders are used and the assemblage is secured with the help of bolts and screws. The working platforms are supported on brackets, bolted to the inner row of standards. At intervals ladder scaffolding requires to be secured by additional corss pieces tied to windows as shown by thick lines in the figure.

Art. 208. Chimney Seaffolds—The Seaffolds for the chimney may be built either *internally or externally*, the work of raising the scaffolding kept sufficiently in advance of the chimney construction. The standards for internal scaffolding are supported by bearers laid on the internal set-backs of the chimney brickwork. Hinged trap doors are

provided in the middle of the working platform for access and delivery of materials.

For *a tall chimney* and where the brickwork is more than 1'—6" thick, it bceeomes difficult to reach and to properly finish the external joints from the inside. For this purpose, the scaffolding is erected externally. See Fig. 547. The outer standards are firmly secured into the ground and the inner ones rest on sleepers. The lifting of materials to working platforms is done with the aid of hoisting tackle fixed to the outer standards. As usual the scoffolding requires stiffening by cross braces which are lashed across from standard to standard.

For the constuction of *Spires*, the chimney external scaffold is slightly modified by using raking standards which are erected in sections. The raking standards are firmly spliced with fish plates, and diagonal braces are securely lashed at every stage.

Another form of Scaffolding known as climbing Scaffolding is also used. This does not rest on the ground, but at its lower part, it is given a grip by securing it to the proviously constructed part of the chimney.

As the work proceeds, the Scaffolding also is made to climb up.

Art. 209. (i) Stagings—For the construction of works where heavy materials and large blocks of masonry, girders, etc. have to be handled, a substantial form of scaffolding is required. The lower portion of the scaffolding is widened to form a staging like an elevated platform, often sufficiently wide to provide a space for a travelling crane. The timber sections used for staging are roughly square. Essentially a staging consists of a framework of uprights resting on sleepers and jointed on top with the aid of cross pieces called leads. The frames are stiffened by diagonal cross braces in the form of struts. The elevated platform is formed of supporting

joists and continuous planking. Ordinary type of staging is also used to carry out the work in connection with ceilings of buildings such as, plastering, repairs, or decorative work. The details of a simple staging are shown in Fig. 548.

(ii) *Dome Scaffolding* is essentially a staging work except that the working platform is formed at an elevated

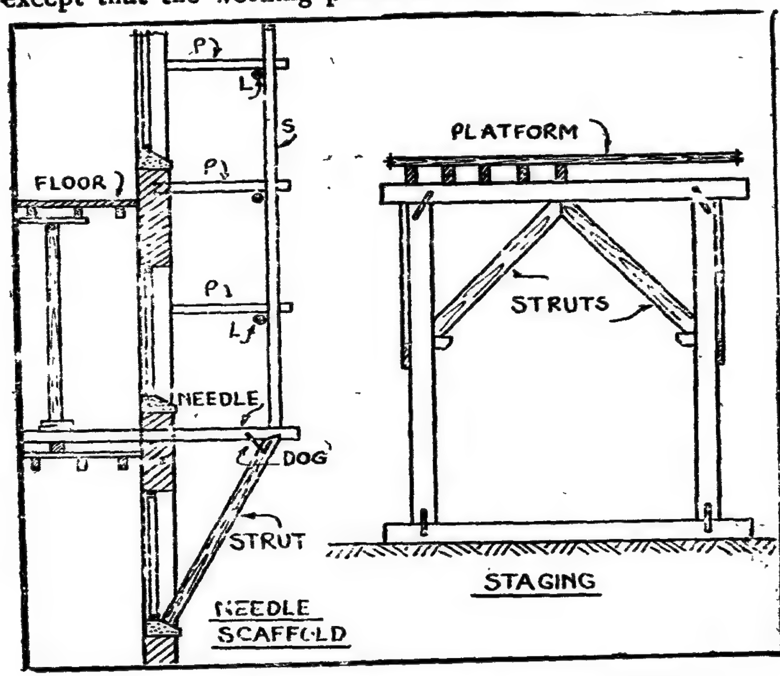


Fig. 543. Details of staging, showing the working platform.
Fig. 548. Details of a needle scaffold; showing the strutting.

level to support a secondary scaffold so as to be within the easy reach of the dome soffit. Sometimes to obtain the necessary stiffness and strength required for such tall stagings, metal stagings are often recommended to form a main platfrom, on top of which a secondary scaffold is constructed to reach the dome as mentioned above.

Art. 210. Needle Scaffolds—See Fig. 549. When the fronts of buildings are abutting against busy roads or

pavements, which should be available for use by the traffic, the scaffolding does not reach the ground in the ordinary manner. The scaffolding in such cases is supported by a series of cantilevers or needle beams passing through window openings or through holes cut in the walls. The inner end of the cantilever which projects to a suffidient distance inside the biulding must be strutted for being firmly held down, preferably against the beams of the adjoining floors. On the outside also it is a good practice to prop the cantilever end by a strut against the sill of a window. When the needles are thus secured in position, toe scaffelding is raised on them in the usual manner as mentioned in Art. 195. Cantilevr or needle scaffolding is also used when it is reqired to execute repairs or decorative work at higher levels in a building and it therefore becomes too costly to build the scaffolding up from the ground level.

(ii) *Suspended Scoffolding*—This is another variety of scaffolding which belongs to the type where the supporting standards do nnt rest on the ground, and it is intended to have a cheap and easy access to the part of a building for carrying out light construction work. The scaffolding is hung generally from the roofs by means of ropes or wire and a travelling craddle is provided for workmen and materials at its lower end. The travelling cradle can be mechanically raised or lowered or even moved sidewise as required.

Art. 211. Steel Scaffolding—The use of metal, usually steel, as a scaffolding material in place of wood, has greatly facilitated the art of scaffolding recently. Steel tubes of about 2 ins. diameter and of standard lengths are used. The various component parts such as standards, ledgers, putlogs, ete, are the same as those of a timber scaffold. Special patent couplings and set-screws are used to connect the various members. by the use of a steel scaffolding, the time used in erection and dismantling is much shorter than that repuirred for a wood

scaffoldiug. It is also more economical when the scaffolding work is great. Metal scaffolding is more rigid.

Art. 212. Gantries—The term gantry is speeially used to indicate a double staging of a heavier type, either of timber or of steel for the purpose of carrying a travelling crane. On top of the staging, runners are provided on which

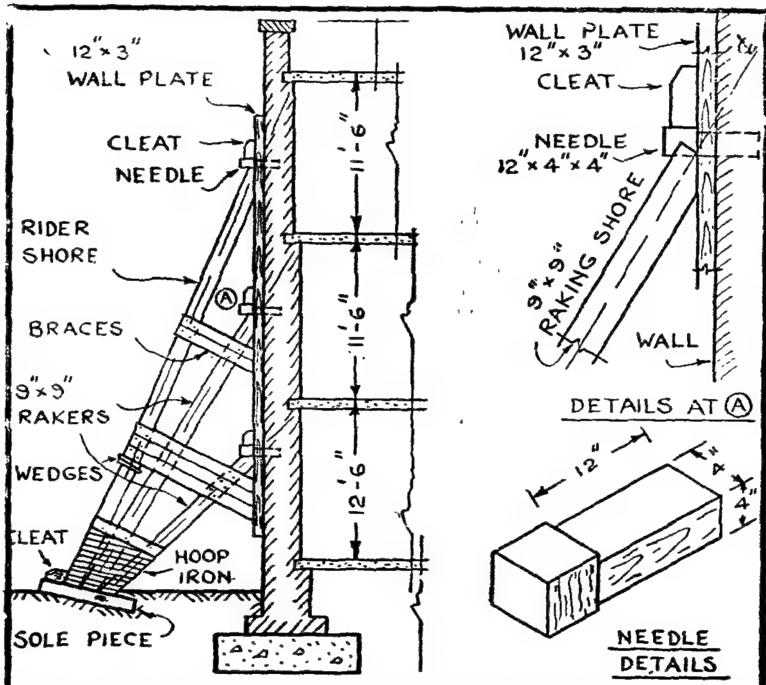


Fig. 550. Details of raking shores for different floors.
Fig. 551 and 552, Needle details and method of fixing rakers to the wall.

the rails are fixed to carry a travelling platform and to enable it to move along the length of the gantry. The travelling platform is also provided with rails on top and in its turn carries a lifting tackle which moves on these rails, in a direction perpendicular to the length of the gantry. By arranging the two stagings, one on each side of the wall, it is very convenient to use this traveller gantry for lifting, handling

and correctly placing in position, heavy blocks of stones and moulded work in the wall. The gantry requires stiffening with the aid of struts placed against the standards.

But the term gantry is however used to include any staging, erected as a temporary structure to provide a working platform either to support the scaffolding cranes as described under staging above. It is then best known as platform gantry.

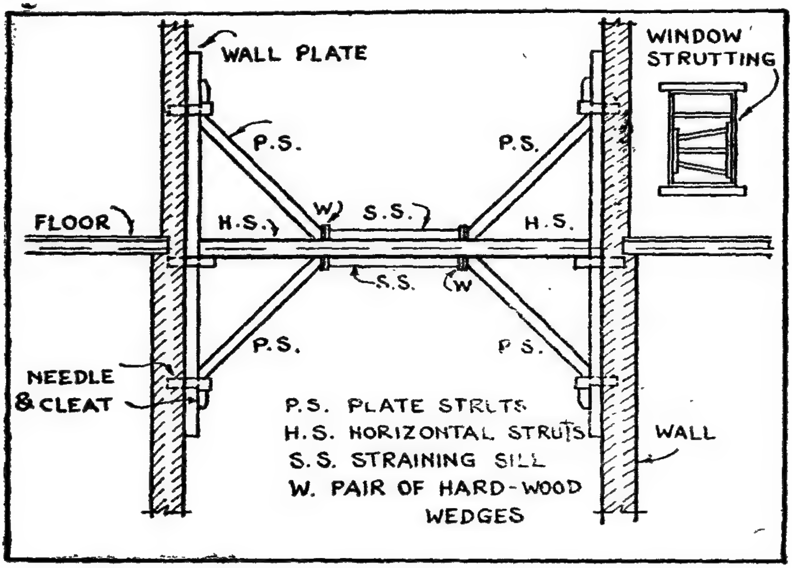


Fig. 556. Showing a flying shore in position. Note the window strutting.

Shoring and Underpinning.

Art. 213. Shoring and its Varieties—The term shoring is used to indicate temporary support to unsafe structures, whose stability has been endangered either due to a new building to be erected in its immediate neighbourhood which may result in the settlement of the foundation; or due to the removal of adjacent building; or due to the repairs to be carried out for defective foundation and bad workmanship.

Shorings are usually classified ar *Racking Shores*, *Flying Shores*, *Dead Shores*. These will now by described in detail,

Art. 214. Racking Shores—The unstable part of the structure is conveniently supported with the aid of raking or inclined shores, as shown in Fig. 550. One end of the shore rests on the ground and the other abuts against the wall of the building to be supported. It will be seen from the figure that raking shores essentially consist of baulks or rakers of timber placed inclined and held together at the ground level. The other ends of these rakers are placed against a wall plate and are secured to it by square needles. The needles are driven into the wall and fit into the notches cut at the ends of the rakers. See Fig. 251 and 552. Cleats are placed on top of the needles and allow them to prevent the wall plate from sliding against the wall. In the case of a multi-storied building, one raker is placed at the junction of each floor with the wall. The top-most raker is termed as the rider shore.

The various rakers of a raking shore are rigidly framed into a triangular system with the aid of braces at intermediate lengths. The feet of the rakers are finally bound together by braces and hoop iron binding also. They rest on a common sole plate against a solid ground. To make the shoring quite effective an inclination of 45° for the rakers is desirable. But very often, for want of greater room, steeper inclinations have to be adopted in practice to suit the amount of space at disposal.

Art. 215. Flying Shores—these are used for supporting temporarily the walls of two adjacent buildings, which may tend to collapse due to the removal of the intermediate building designed to be reconstructed. See Fig. 553. The principal parts of a racking shore (i) a central member strutting horizontally as a stiffening beam shown by H. S. in the figure; (ii) Inclined struts P. S. fixed under and over the above horizontal strut near its eads; (iii) Wall plates, cleats and needles as in the case of raking shores; and (iv) Straining

sill with pairs of hard wood wedges at their ends. The principle on which a flying shore is designed is the same as that of raking shore, viz. the formation of different triangles in the frame work.

In the *erection* of raking and flying shores, first operation is to fix correctly the positions of the wall-plates and the

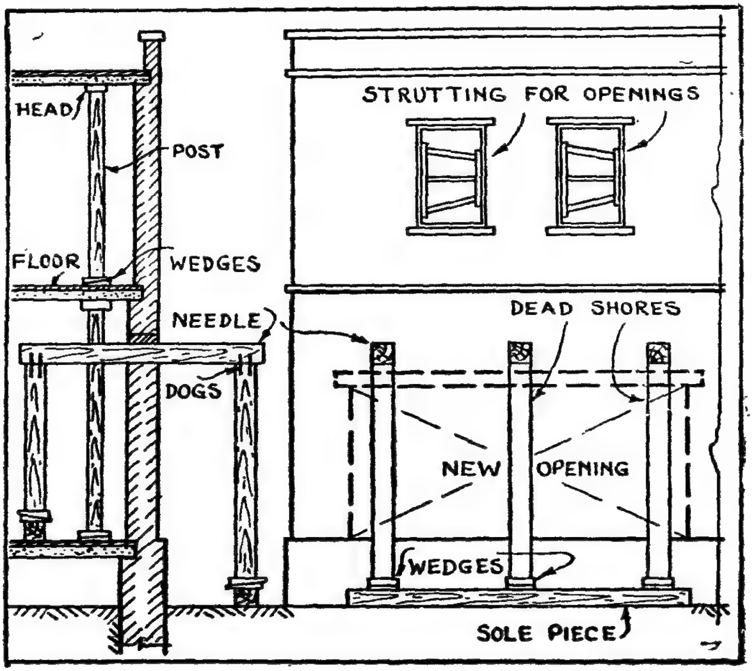


Fig. 554. Showing the details of dead shores.
Fig. 555. Elevation of the above, indicating the method of providing a new opening.

insertions of the needles and cleats. The rakers, horizontal and inclined struts are then placed in their proper position.

Art. 219, Dead Shores—These are vertical shores intended to act as temporay props to give support to a wall in connection with the rebuilding or the removal of its lower part for a new foundation; or to provide large openings in it

for new doors, windows or shop fronts at lower levels. The details of dead shorse are given in Fig. 554.

In the process of providing dead shores to a building, the initial operation is to strut the door and window openings squarely to resist any deformation, as shown in Fig 555. The next operation is to strut the floors inside the building to relieve the supporting wall of the floor load. These vertical struts are formed of 6″×6″ to 10″×10″ timber props. At the top and at the foot of these struts, sills and sole pieces should be provided to distribute the load. Holes are then cut in the wall at points above the required opening, at a distance of about 5 to 6 feet apart. Through these holes, horizontal wood or steel beams, called needles, are inserfted to projecton both sides of the wall, the ends of these needles being supported by heavy props, wood blocks or cribing, as found necessary. It should be noted that pairs of wedges should be used at various places, in erecting dead shores.

Art. 217. Underpinning—Very often it is necessary to strengthen the foundations of existing buildings having shallow footings, when a building with deep foundations has to be erected adjoining to it. This work has to be carried out without affecting the stability of the existing properties and their walls have to be supported until their foundations are rebuilt or are extended to the depth of the new building. This work is termed as "Underpinning". Underpinning is also resorted to for rebuilding parts of walls above ground level.

As mentioned above, the operations involved during underpinning very often require the existing structures to be temporarily supported until the new walls and foundations are permanently built. The underpinning operation largely depends upon the fact that bonded masonry work is able to remain in the form of an arch over an average sized breach made in it. The ends of arches thus formed are supported by needles described in the previous article under dead shores, and also as explained in the following article.

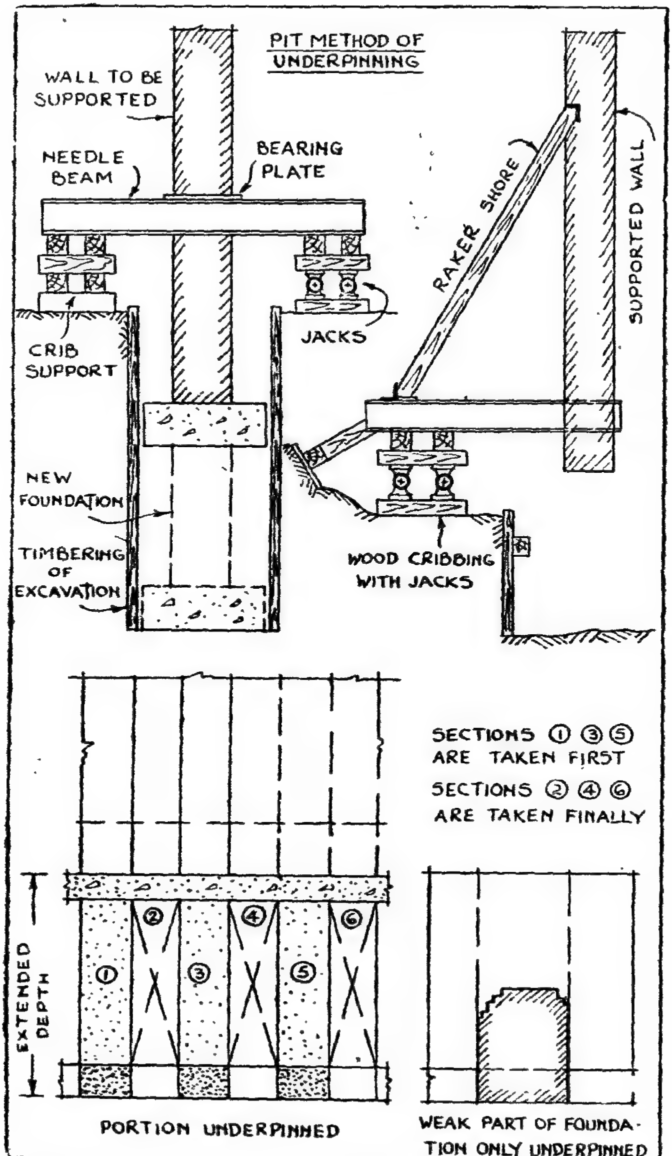


Fig. 536. Pit method of underpinning with the needle beam.
Fig. 557. Pit method of underpinning with the cantilever needle beam.
Fig. 558, Underpinning long walls in alternate section.
Fig. 559. Showing the strengthening of only a weak part of foundation.

Art. 218. Methods of Underpinning—The following are the two general methods by which underpinning is provided,—

(i) The Pit Method.
(ii) The Pile Method.

The pit method requiries the excavation be carried upto the full depth of the proposed new foundation and the whole

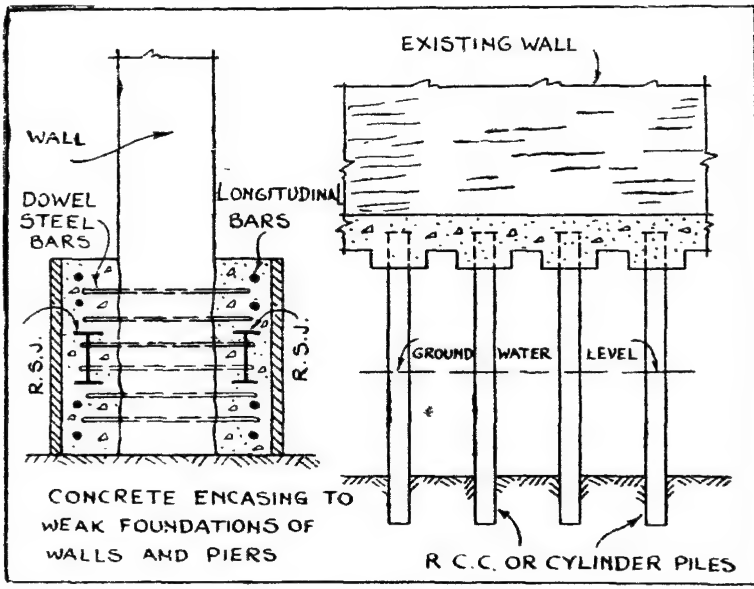


Fig. 560. The pile method of underpinning.
Fig. 561. Strenghening of wall foundation by encasting.

length of the wall is built up to the under side of the wall to be underpinned. This method is shown in detail in Figs. 556 and 577. The needle beam shown in Fig. 555 rests on crib supports and the new extended foundation is shown by dotted lines. In Fig. 557 is shown the method of supporting a wall for underpinning by using a cantilever needle beam. In each case jacks are used under the supports. The entire length of the wall is divided into various sections marked 1, 2, 3, 4....and so on, and each time a section is excavated by supporting the sides by shores. The excavated

portion is filled in by masonry, brickwork or concrete. Usually alternate sections are taken up in the first stage and finally the intermediate ones are filled up. See Fig. 558. When only a part of the wall has to be strengtened, it is built up as indicated in Fig. 559.

(ii) *The Pile Method*—Sometimes the presence of water in the foundations does not permit of pits to be excavated to the final depth required to support the wall. In such cases, precast R. C. C. piles may be driven to the calculated depth, either with the aid of a falling weight, or by a pneumatic hammer, or under the pressure of a hydraulic jack or ram. The R. C. C. piles may be replaced by steel cylinders of about 10″ to 12″ diameter. The cylinders are finally filled with concrete. Large diameter cylinders are also employed and are sunk pneumatically.

The tops of piles are then provided with caps, just below the level of the wall to be underpinned and the remaining gap is filled up with masonry or concrete. See Fig. 560 for datails of the pile method. Pile method is specially suited for heavy loads and great depths.

The two methods of underpinning described above are also applicable to isolated column foundations. In the pit method, half the area of the column footing is taken each time.

Art. 219. Strengthening of Foundations—Strengthening of wall and column foundations by increasing the depth of excavation by various methods, has been detailed above. But sometimes foundations of existing walls are strengthened without removing or rebuilding them and thereby eliminating the process of underpinning. This is done by encasing their lower portions with concrete as shown in Fig. 561. Reinforcing rods are passed through the wall—see dotted lines—and also along the wall. They may be replaced by R, S. joists or sometimes a combination of reinforcing rods and R. S. Joists is employed.

Art. 225. Precautions during Scaffolding, Staging and Underpinning—Owing to the general idea that these works are all of a temporary nature, there are possibilities for not devoting the requiste amount of attention to their structural requirements. It is therefore very often feared that many defects may escape the notic of the constructional engineer which may result in casual scaffolding accidents to workmen. Therefore the materials and appliances must be sound and strong and the erection work should be carried out in a perfect workmanlike manner so that the entire temporary carpentry work possesses proper stability and ensures the safety of workmen.

The scaffolding standards should rest on a firm ground and whenever one length has to be extended by joining another, proper lapping should be provided. The working platform should be at intervals of about 6 feet vertically and shall be made of closely laid boards. to a width of at least 18 inches. The stndards should be placed at a spacing of 10 tn 12 feet and every fourth s tandard should be stiffened by diagonal bracing.

CHAPTER XVII

Roof Coverings and Drainage of Roofs

General characteristics of roof coverings.--pitched roofs and flat roofs. Classification of pitched roof coverings. Ground work for roof coverings. Thatched roofs. Shingles,--wood, asbestos cement and asphalt. Slates. Terms used in slates and slating. Slate laying---centre nailing and head nailing Flat and curved panntiles, Half round country tiles, Mangalore or corrugated tiles, Corrugated Iron and asbestos cement sheets.

Water-proofing of flat roofs. Mud roofs. Brick concrete water-proofing. China mosaic water-proofing, Mastic asphalt and bituminous sheeting.

Drainage of roofs. Flashing Rainwater gutters and rain water pipes and their fixing.

Art. 221. General—The coverings for roofs are classified in general as those required for (i) Pitched roos and those for (ii) Flat roofs, to follow the same type of classification for main roofs. Sometimes attempts are made to classify the roof coverings based on the materials used for their making, such as clay, asbestos cement, concrete, asphalt and metallic roof coverings. In the following articles a brief description will be given of the methods of providing roof coverings based on the different kinds of materials used with reference to the types of roofs where they are employed.

The adoption of one kind of roof covering or the other depends on various fectors such as cheapness at first cost and maintenance. availability of materials, durability under varying atmospheric conditions of sun, rain and frost, appearance, and the possibility of utilising the roof area. The principle on which the roof coverings are designed is based on the formation of ridges, valleys, and hips, and it may be noted that these are the weak points in roof coverings where their continuity is broken and due attention should be given to eliminate the leakages. This simultaneously leads us to the

problem of laying down an effective system of roof drainage with flashings of lead or other materials as explained later, to prevent water from penetrating through the vertical joints.

Pitched Roof Coverings

Art. 222. Classificafion of Pitch Roof Coverings—Róof coverings are mainly classified into the following eatagories:—

(i) Thatch.

(ii) Wood shingles.

(iii) Slates.

(iv) Flat and curved pantiles.

(v) Half round country tiles.

(vi) Mangalore or corrugated tlies.

(vii) Corrugated iron or asbestos cement sheets.

The slopes given to pitched roofs usually varies from 25° to 45°. depending on the materials of roof coverings used; and that used for flat roofs varies from 1 in 10 to 1 in 80.

Ground Work for Roof Coverings—All roof coverings require a certain amount of ground work which mainly consists of suitable combinations of rafters, purlins, boarding along the slope or across the slope of the roof, bitumastic felt, roofing paper, counter battens along the slope and ordinary battens across the slope. The roof covering enumerated above are laid on top of this ground work. The formation of the substructure of a roof is explained in Chapter XIV, with the necessary refence to the roof covering.

Art. 223. Thatched Roofs—Thatch forms the sheapest and the lightest materinl for roof covering. It consist of bundles of reeds or straw fixed to battens, which are cheaply formed of round and split bamboos. The thickness of the thatch varies from 9 to 15 inches and the slope of the roof is usually kept at 35° to 45°. The usual drawbacks of a thatched

roof are its susceptibility to catch fire, its tendency to rot and give out fowl odour, specially by absorbing moisture. The life of a thatched roof is not more that 15 to 20 years. Sometimes attempts are made to impart fire resisting properties to thatch by soaking it in specially prepared fire resisting solutions. The reeds or straw are tightly secured to battens with the help of special ropes and twine dipped in tar.

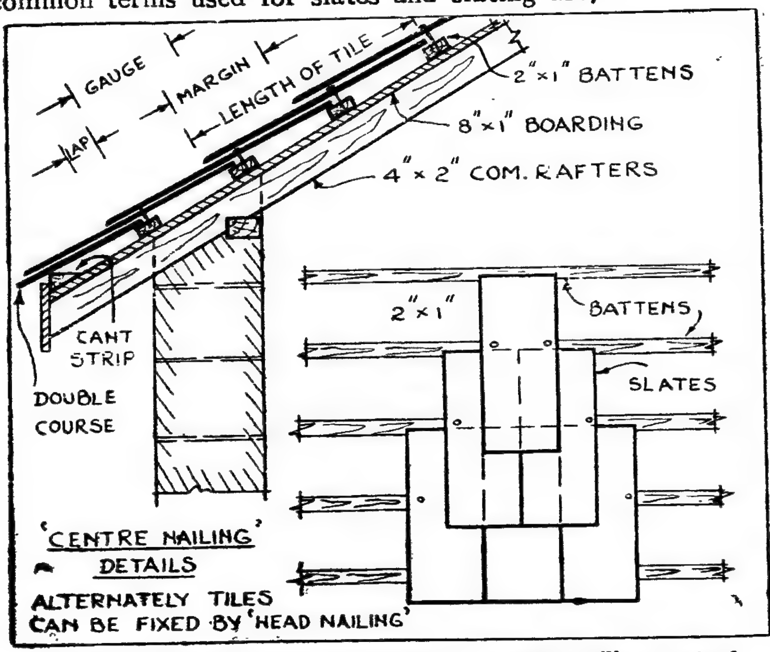
Art. 224. Shingles—Wood shingles are sawed or split thin pieces of wood resembing slates or tiles. Split shingles are better than sawed ones as in the latter case the wood cells are cut open. However, sawn shingles can be dipped in creosote to impart preservative qualities. To form continuous roof covering wood shingles are laid in a manner similar to that of laying slates as described latter. Shingle strips are driven on rafters and shingles are nailed on their top. At the eaves end two courses of shingles are laid directly one over the other. Shingles are commonly obtained in lengths of 16, 18 and 34 inches.

Shingles can also be manufactured from asbestos cement and asphalt in sizes of 6″ × 12″ to 12″ × 16″, to imitate wood shingles. They are fire proof in nature. Asbestos shingles are composed of about 15 *per cent* asbestos and 18 per cent cement prepared under great qressure in a powerful hydraulic press; while asphalt shingles are manufactured of felt impregnated with asphalt, Asphalt shingles are soft and therfore can be obtained in strips of 12″ × 36.″ In the case of asbestos and asphalt, it is desirable to lay a close roofing of timber boarding over rafters to support them. Preferably roofing paper may be interposed between the boarding and the top roof covering of shingles.

Art. 225. Slates—Slate forms the most durable of all the roof coverings. It is obtained from quarries and on account of its marked clevage and laminar structure, it can be split readily into thin sheets. It is used as a roofing material from very early days. It does not change its colour with time. The

common commercial sizes of roofing slates are varying from 24"×16" to 10"×6" and their thickness is usually ¼". A good slate is hard and tough and emits a sharp metallic ring when struck with finger. When holed it should not split. The absorption of a good variety of slate should not excecd 2 per eent of its weigth.

Art. 226. Terms Used in Slates and Slating—The common terms used for slates and slating are,—



Figs. 552 and 553, Showing the details of centre nailing method

(i) *Back*—The upper surface of a slate.

Bed—The under surface of a slate.

Head—The upper edge of a slate.

Tail—The lower edge of a slate.

(ii) *Margin* is the portion of the slate exposed to view on the outside of a roof. See Fig. 562.

(iii) *Lap* is the distance by which the taill of the upper slate overlaps the head of the slate below it.

(iv) *Gauge* is the distance between the tails of the two adjacent slates when laid.

(v) *Tiling Fillet* or *Cant Strip* is the triangular fillet fixed under the eaves course.

Art. 227. Slate Laying—Slates are laid in either of the two following ways.—

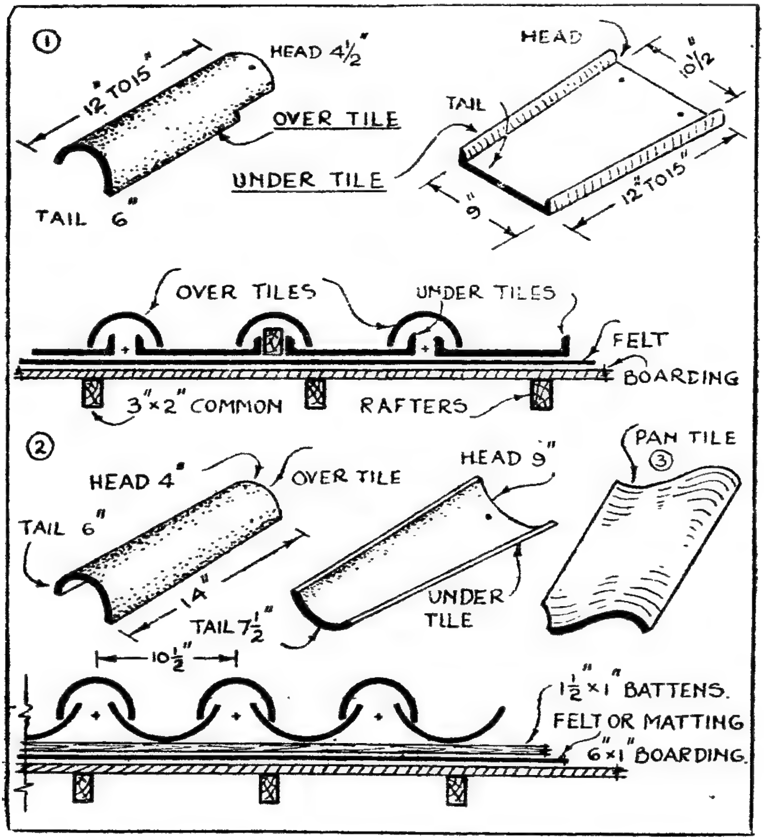
(i) *Centre Nailing*-Holes are pierced slightly above the centre of the slate to fix them on battens $2'' \times \frac{3}{4}''$ or $1''$ thick. The battens in their turn are nailed to rafters at gauge distance. See Figs. 562 and 573. In this case the gauge equals $\frac{1}{2}$ (length of slate + lap.)

(ii) *Head Nailing*—In this method holes are pierced at at distance of $1''$ from the head and $1\frac{3}{4}''$ from the sides. The gauge in the head hailing equals $\frac{1}{2}$ (length of slate + lap + distance of nail hole from head). Centre nailing affords better protection against strong winds, whereas head nailing has the advantage of protecting the nails.

Eaves, Hips, Ridges and Valleys—In both the above methods of slating, eaves are formed by double courses. Hips are treated with special hip tiles. Alternately, the normal slate courses are laid to the hip and the end slates are mitred to the hip slopes. Lead flashing and bitumastic cement are used to make the joint water-tight. Ridges are also formed in a manner similar in construction to that adopted for hips. Half round tiles are used to form a saddle ridge or slates are cut and a tight joint is formed with bitumastic cement. Velleys may be formed both open and close mitred. An open valley has at least a width of 6 to 8 inches and is wider towards the eves.

Art. 228. Flat and Curved Pantiles—The usual terms mentioned in slating are also applicabletotiling. Pantiling is one of the oldest methodof providing roof coverings. Pantiles may be either of clay or of asbestos cement. Typical pantiles are shown in Figs. 569 (clay pantile) and 577 (cement

asbestos pantile). Clay pantiles are manufactured in a manner similar to that of bricks. Pantiles can be fixed cheaply to battens, but as they have single lap bythe sides, and at the head and tail, it is necessary to provide ground work consisting of a continuous layer of boarding and roofing paper of



Figs. 564 snd 565. Circular cover tile and flat under tile.
Ffg, 566. Method of laying the above tiles.
Figs. 567 and 568, Semi-circular over and under tiles.
Fig. 569. Clay pantile.
Fig, 570. Method of laying semi-circular tiles.

unterable felt. Over this layer, counter battens 2″ × ¾″ are laid longitudinally along the slope, one on each common rafter.

The normal cross battens $1\frac{1}{2}'' \times \frac{3}{4}''$ are laid across the slope, On these counter battens and over them the pantiles are laid directly. But double lap pantiles will not require a continuous support of ground work as decribed above, and could be laid directly on cross battens driven on common rafters. The slope could be about 45° in this case. The tiles are slightly cambered in the centre and carry nibs at the head. Ridges are formed by half round or hog-back ridge tiles. Lead flashing is liberally used in the formation of hip and valley gutters in pantiling.

Art. 229. Half Round Country Tiles—These are laid in pairs of under tiles and over tiles with proper lapping

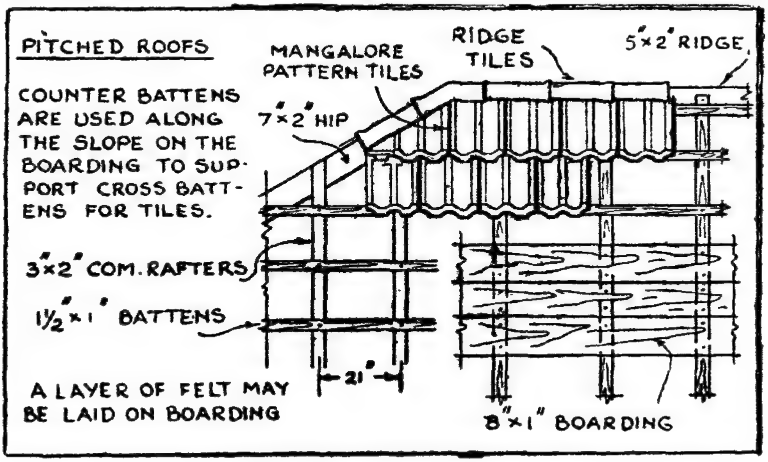
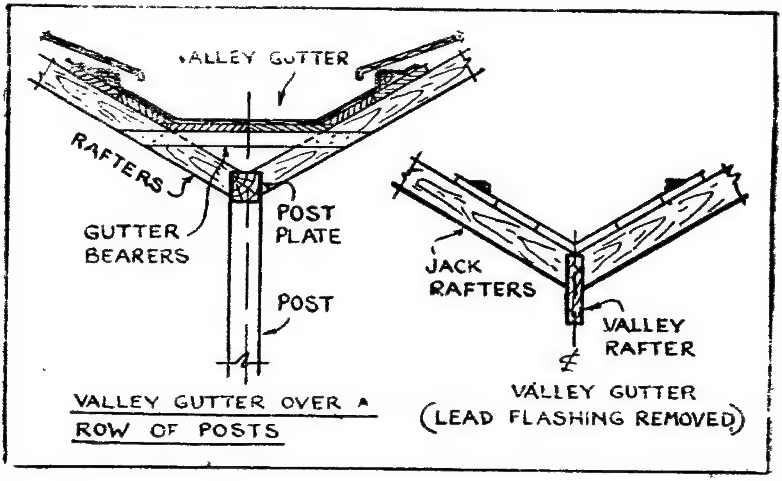


Fig. 571. Mangalore tiled roofing.

on all the sides. Generally there are two varieties of such tiles. In one variety the under tiles are flat with a broad head tapering towards the tail, and an over tile, at shown in Figs. 564 and 565. The over tile has a wider tail and a narrower bead. In the second variety, the over and under tiles are both semicircular and their dimensions are shown in Figs. 567 & 568. These tiles are laid on a ground work of boarding or closely driven battens. Preferably a layer of felt or matting should be provided on this before the tiles are laid. See Figs. 560 and 570. where the laying of these

two types of tiles is illustrated. This is a very cheap type of roof covering and is very commonly used economically in combination with split bamboos in place of battens. The last row of tiles, near the eaves and the ridge, the valley and the hip, are laid in lime mortar. Country tiles are also laid in two layers one over the other and the roof is then called a "Double Tiled Roof". The tiles are sometimes provided with holes near the head, so that, they could be tied down by wire, if the slope is very steep and when there is a possibility of their being disturbed by wind.



Figs. 572 and 578. Showing methods of forming valley gutters.

Art. 230. Mangalore or Corrugated Titles—A more decent and lighter roof covering can be provided with the aid of Mangalore tiles. The gound work for these tiles, in a very ordinary case, consists of battens only, and for superior work a layer of boarding and an additional layer of felt over the rafters. Counter battens and cross battens are then laid to support these tiles. The method of construction of such a roof with or without boarding is shown in Fig. 571. Ridges and hips are formed in the usual manner by using special tiles intended for the purpose. They are laid dry and pointed with

lime or cement mortar. But the valleys are formed with the aid of lead flashing laid over boarding as shown in Figs. 572

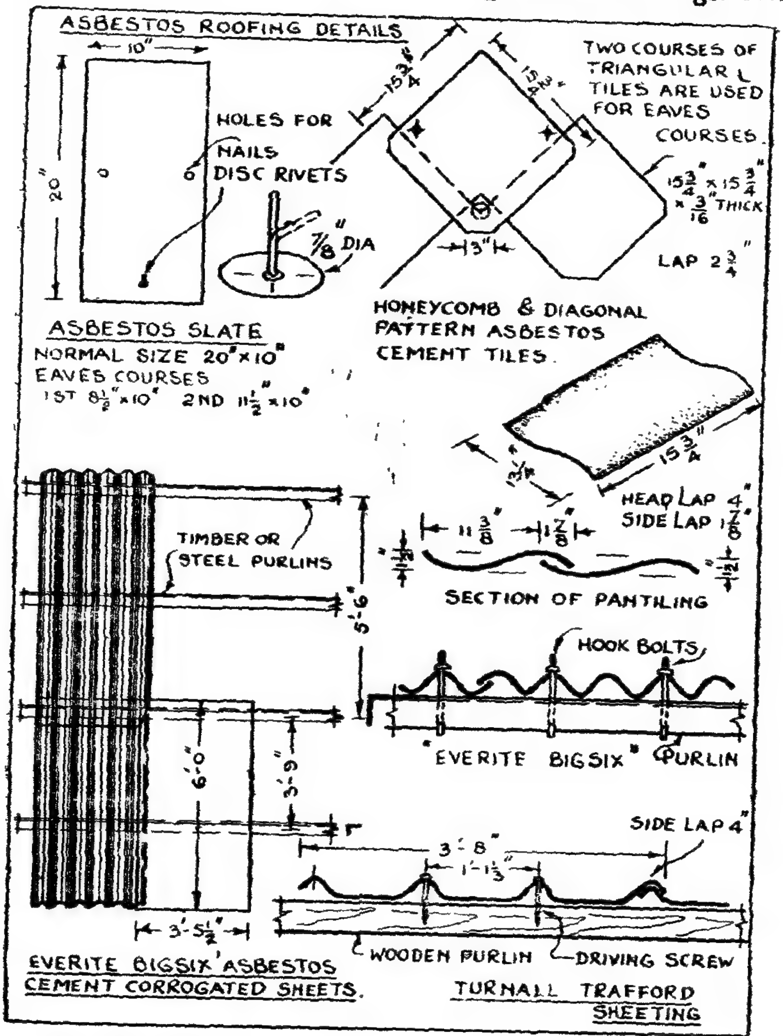


Fig. 575. Asbestos straight honey comb or diagonal slates.
Fig. 576. Disc rivets for fixing the above.
Fig. 577. Asbestos cement pantile.
Fig. 578. Section showing the laying of pantiles.
Fig. 579. 580 and 581. Asbestos cement sheet roofing details.

aud 573. These tiles are heavily grooved on the top and at the sides to provide proper drainage and interlocking with the adjacent tiles. They provide maximum coverage with minimum material. In case of necessity, holes can be drilled in their ridge portion to secure them by wire to the ground work.

Art. 234. Corrugated iron or Asbestos Cement Sheets—In recent years asbestos cement is very commonly adopted as a roofing material. Almost all varieties of roof covenings are made with asbestos coment. As the name implies, this material is composed of asbestos fibers and cement in the ratio of 1 part of asbestos to 7 parts of cement and subjected to great pressure as mentioned before.

Asbestos cement slates are made either straight, heneycomb or diagonal. See Figs. 574, 575 and 576, Special size slates are used to form eaves courses. The pitch of roofs varies from 25 to 40 and the end lap is proportlonately decreased from 4″ to 3″ as the slope increases. The tiles fixed to the ground work by nails and disc' rivets.

Asbestos cement pantiles are also manufactured and are laid in a manner similar to the clay pantiles described before. See Figs. 577 and 578.

TABLE NO. XIII

Particulrs of Asbstos Cement Sheets.

Type of Sheets	Width when laid	Thick ness	Side laps	Corru-gations	Pitch	Depth
Fverite Big Six	3′–5½″	1″	2″	7½″	5¾″	2⅓″
,, Standard	3′–6″	¼″	4″	10	2⅞″	2⅛″
Turnalltrafford	4′–8″	¼″	4″	4	13⅓″	2″

Art. 392. Asbestos Cement Sheets—Cheap and durable fire resisting roof covering can be formed with this variety of materials. Asbestos cement sheets are obtained principally in three types but in various lenghs from 3 feet to 10 feet, rising in 6 inch increment. Their widths are given in the following table.

These varieties ars;—(i) Everite Big six. (ii) Everite Standard; (iii) Turnall Trafford. See Figs. 579 to 581.

Asbestos sheets are fixed direct to timber or steel purlins.The purlins may be spaced from 3 ft. to 4″-6″ centres. In fact, in an economical design,the spacing of the purlins and the length of the heets is so worked out and adjusted that the end joints of the sheets come on a purlin. The fixing of the sheets to wood purlins is by means of 2″ to 4½″ by ¼″ to ⅛″ galvanized screws with cup washers, see Fig. 580; and to

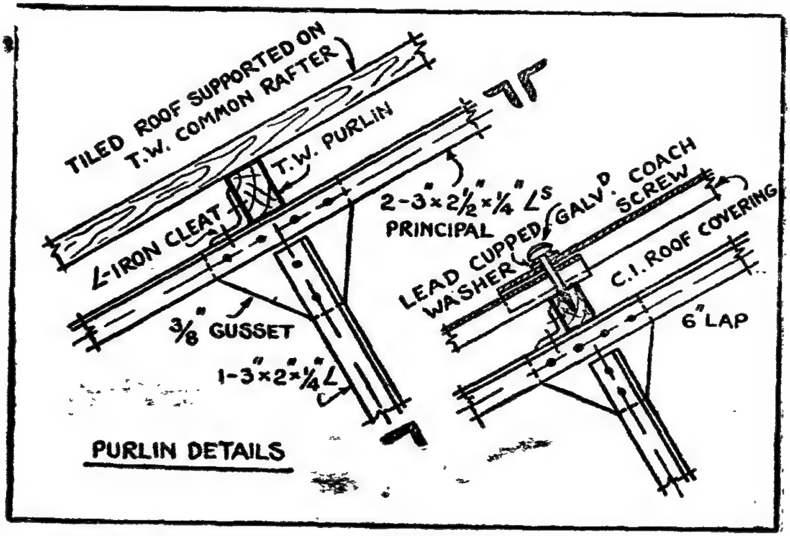


Fig. 580. Fixing of asbestos sheets to teak wood purlins.

steel purlins which may be either angle iron or R, S. Joist the flxing is done by means of hook bolts with cupped washers see Fig. 581. The ridge is formed with the aid of a pair of ridge cappings as shown in the above figure. The holes for fixing the screws or bolts to purline are drilled on the ridges, with their diameter ⅛ bigger than the diameter of the bolt, to allow for expansios.

Asbestos cement sheets are suitable for roofing of cinemas and factories.Lhey are very economical and satisfactory,and

represent a neat and clean appearance. They are tough, durable, and possess fire-resisting properties. The average weight of asbestos cement covering is only 3 to 4 lbs. per sq. ft. Recently, asbestos cement sheets have largly taken the place of corrugated G. I. sheets.

Corrugated galvanized iron sheets are used and fixed in a manner similar to the asbestos cement sheets. Their thickness is expressed in terms of gauges as No. 16 to 24, the uumber indicating the fraction of an inch.

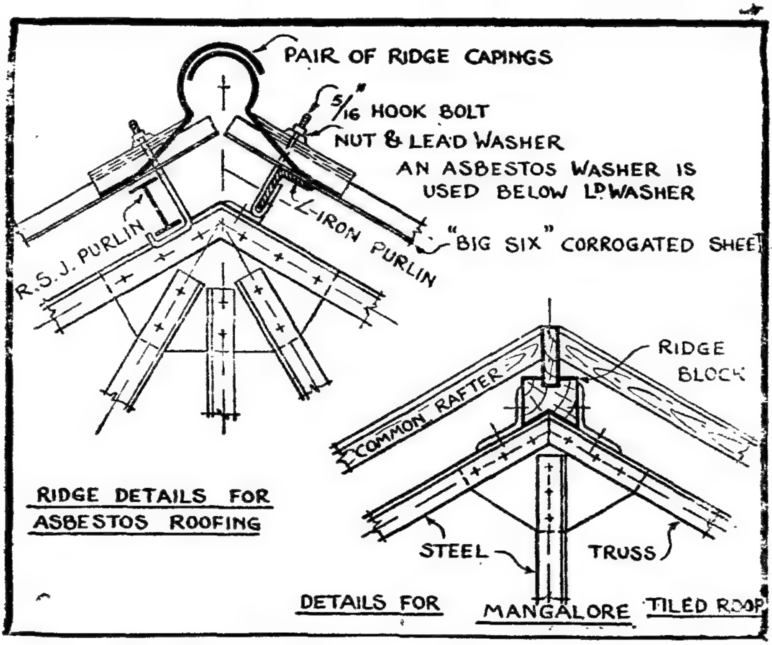


Fig. 581. Ridge details showing the method of fixfng. the sheeting to steel purlins.

Water-proofing of Flat Roofs.

Art. 223. Mud Roofs—Similar to pitched roofs, flat roofs also require a finishing on the top of the roof substrucre, the main purpose of which is to provide a water proofing layer. A very cheap water-tight flat roof can be made with mud, in places where the rainfall is light. For this purpose, only white earth with a large percentage of sodium

salt should be used. The substrrcture consists of rolled steel beams, over which are placed T-irons at 12½″ centres. Well burnt tiles measuring 12″ × 12″ × 2″ or 12″ × 6″ × 2″ are set in lime mortar between these T-irons.

On top of this base work a 6″ thick layer of stiff mud is laid and beaten to a hard mass. Much skill lies in the manner in which this layer of mud is laid and beaten until it becomes hard. A plaster of mud with an admixture of cow-dung is then laid on this previous layer of stiffened mud. The surface is finally finished with a wash of 4 parts of cow-dung and 1 of cement. This wash requires to be renewed from time to time. Sometimes the initial 6″ layer of mud mentioned above, is replaced with three layers 2″ mud and 1″ *bhan* alternately.

The substructure of steel joists, T-irons and tiles in the above method may be replaced by wooden bridging joists and teak wood boards 1½″ to 2″ thick. On this is laid a layer of well burnt bricks on edges and set in lime mortar. This is finally covered by a 4″ to 6″ layer of selected white earth, thoroughly beaten to a hard surface.

Art. 234. Brick-concrete Water-proofing—In places where the rainfall is heavy, layers of mud as water-proofing media are not found satisfactory. The best method, under these cirumstance, is to lay a layer of lime concrete of well graded broken bricks in a thickness varying from 6″ to 3″ and with its top having a slope of 1 in 30. It is advisable to use crude oil, about 5 percent by weight of lime. After the concrete is laid, its top is throughly beaten for 3 to 4 days with pointed beaters, and simultaneously a thick slurry of lime and water is poured so as to prepare a hard and continuous top 1″ thick layer to develop water-proofing qualities.

Tiled Finish-When it is in intended to utilse the terrace as an out-door living room or for fnnctions, a double layer of thin flat roofing tiles 6″ × 6″ × ½″ is laid on the brick concrete detailed above. One of these layers is laid diagonal and the other is laid square. Instead of rectangular tiles,

hexagonal tiles could be used, if it is intended to improve the appearance of the terrace flooring. The tiles are set in combination mortar.

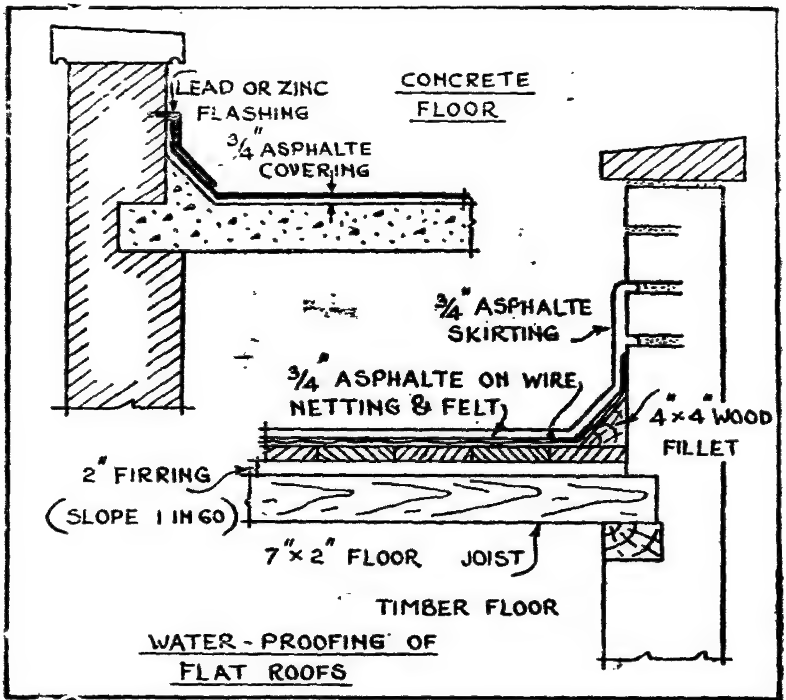


Fig. 582. $\frac{3}{4}''$ asphalt water proofing layer for an R. C. C. roof.
Fig. 583. $\frac{3}{4}''$ asphalt water proofing layer on wire netting and roofing felt for a timber floor.

Mosaic Finish—The double layers of roofing tiles mentioned above can be replaced by a covering layer of pieces of glazed china mosaic set in combination mortar. By adopting different colours for the masaic pieces, any desired design could be laid. China mosaic pieces are hard and non-absorbant and hence offer a very good water proofing source.

In this method of water-proofing by brick concrete, the structural base work may consist of any of the floorings described under floors in Chapters XI and XIII.

Art. 235. Mastic Asphalt and Bituminous Sheeting—In its simplest form an R. C. C. roof slab could be made water proof by a covering layer ¾" to 1" thick mastic asphalf as shown in Fig. 582. Lead flashing and concrete fillet are used at the junction of the roof with the parapet. Mastic asphalt is supplied for building purpose by manufacturers

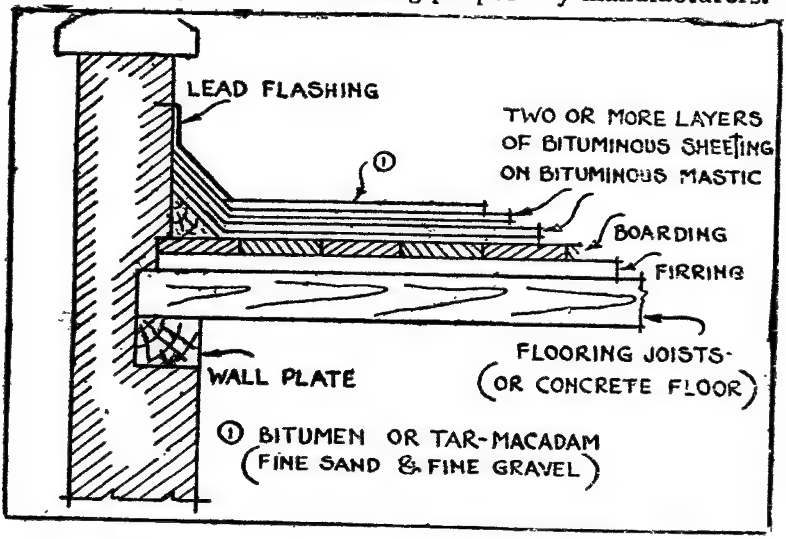


Fig. 584. Details of water-proofing with bituminous layers laid on bituminous mastic.

in the form of blocks or cakes or in drums. It is liquified by heating in iron pots. At the time of laying, it is mixed with girt or broken stone in the ratio of 2 to 1. It should be applied hot and should be immediately worked to the required thickness by trowels.

In another method,a layer of roofing felt and wire netting is laid hefore hot mastic asphalt is applied to provide water proofing. This is necessary for timber floors to which hot mastic asphalt could not be applied directly. See Fig. 583. Fine gravel, sand grit can be spread on mastic asphalt to increase its durability.

Sometimes two or more layers of bituminous sheeting, interposed with layers of bituminous mastic are laid as a

water-proofing medium, as shown in Fig. 584. Several proprietory bituminous sheets for roofing are manufactured by different firms and are avaiable in roofs of different sizes.

Art. 236. Flashing—Flashing is the term applied to sheets of lead or other metal used to prevent water from leaking through the joints,—

(i) When two planes of the same slope meet as in the case of hips, ridges, closed and open valleys; or

(ii) When the vertical faces intersect with the plane of the roof as in the case of chimney stacks, dormer, parapets, raking parapets of gable roofs, hidden eaves gutters of pitched roofs along a parapet wall, skylights and lanterns.

The sealing of these joints is of the greatest importance. Metal sheets are introduced either of copper, tin, zinc or lead to over-lap these joints. Flashing may also be of heavy impregnated felt or even a combination of metal and felt. Galvanized steel sheets are unsatisfactory as they corrode in the course of time. A chimney flashing is a thorough flashing and it is turned up for water-proofing. The flashing is in two parts and essentially consists of a base and a cap flashing. The base flashing is fitted into the tiling and bent up along the side of the chimney brickwork. The cap flashing has its upper edge built-up in the brick manonry of the chimney stack as the brickwork is laid, and its lower edge is cut on a diagonal to match with the pitch of the roof. The top flashing overlaps 4″ to 6″ the vertical portion of the base flashing. This not only helps the method of constructing a flashing, but also provides for an expansion joint for the metal flashing. This is an essential factor, as the metal flashings in an exposed condition, are subject to changes in temperature and due allowance must be made for thermal expansion. The metal flashing, if wider than 12″, should therefore be fixed along one side and free to expand at the other. Other methods of flashing under different conditions of roof drainage are also based on the above principles.

Art. 237. Rain Water Gutters and Rain Water Down-taken Pipes—In the case of pitched roofs, rain water is drained along the roof slopes into the valley and eaves gutters to be further conveyed into rain water down-take pipes. Rain water gutters are made in lengths of 6 ft. and are half round in section. Sometimes curved and moulded sections are also used to suit each case. Rain water down-take pibes are usually circular and of diameter ranging from 3″ to 6″ and in length 6 ft. They carry a deep socket at one end and are provided with ears or lugs cast one on either side of the socket. The lugs help to hold the pipes against the walls. When the lugs are not provided, the pipes are fixed with the aid of metal clips or metal straps. At projections and off-sets in wall, special elbows called "*goose-neck*" or "*swans-neck*" are provided. A rain water head of the shape of a funnel and a shoe are also provided at the top and at the foot respectively, of each rain water pipe.

CHAPTER XVIII

Pointing, Plastering and Interior Finishing

Pointing general principles. Mortar for pointing. Method of pointing -Raking of joints, application of mortar. Finishing the joints. Flat or flush pointing. Weathered or struck pointing. Recessed pointing. Keyed or groove pointing. Tuck pointing. V--pointing.

Plastering--general. Mortor for plaster. Method of plastering--preparing of surface; plaster ground work; plaster coat- Lath and plaster. Use of lath in plaster. Wood lath. Metal lath. Plaster boards. Special finishing to plaster surface,---special compounds used. Rough finish. Sand finish and pebble--dash.

Art. 238. Pointing—General—During the construction of masonry work either of brick or of stone the joints near the faces of walls are generally left rough for a special treatment subsequently. This also helps the masonry work to proceed with great rapidity. Sometimes a neat finishing of joints in a desired manner after the wall is built required to improve the appearance of the structure. But this subsequent treatment at the joints which is known as pointing is mainly a structural necessity. It imparts durability by preventing rain-water and frost from entering the interior of the masonry work through the joints. It may be noted that joints are weak points in a structure and should be properly protected from the disintigrating effect of sun, rain and frost. Sometimes the joints are nominally struck as the work proceeds. This is not a satisfactory method so as to justify a neat final treatment.

Mortar for Pointing—The mortar required for pointing may be either of lime or of cement and is usually of a richer proportion than that used for masonry.

If lime mortar is used it should be double-ground, that is, after the first grinding it should be reground after about 10 days. For cement pointing the mortar should be composed of one part of cement to two parts of fine, clean sand and for lime mortar it should be composed of one part of good well

burnt lime to one part of sharp clean sand. However it should be remembered that the pointing work does not last permanently but requires replacement from time to time by repointing.

Art. 239. Method of Pointing *Raking-out of Joints*—For a new wall it is advisable that the joints should be pointed when the interfor work of the masonry is green. All the joints on the face are raked out by a special pointing tool to a depth of about $\frac{3}{4}$ inch, so as to give a proper and firm grip for the mortar used in pointing. The joints and the wall surface are thoroughly wetted and cleaned with brush. to develop the necessary adhesion.

Application of Mortar—The mortar is laid inside the joint with a small trowel and pressed well to have a solid contact, with the internal joint so as to leave no hollow at the junction. This is very important since a loose filling always results in the peeling-off of the pointing at a latter stage. The work should be kept wet for about a week by repeated watering.

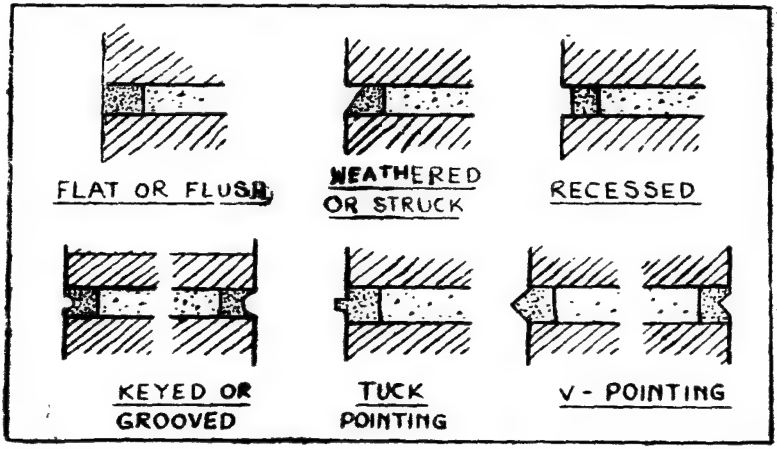
Art. 240. Finishing-off the Joints—The joints are finished off neatly in one of the following ways:—

(*i*) *Flat or Flush Pointing*—See Fig. 585. A simple method of pointing consists in pressing the mortar with a trowel, into the joint previously opened out, and then removing the excess of mortar beyond the face of the wall leaving the joint flush with the face.

(ii) *Weathered or Struck Pointing*—See Fig. 585. This type of pointing is very commonly used. The face of the point instead of being kept vertical the top line is pressed slightly inside so as to make the face of the pointing slope outwards. This has a better effect of throwing off the rain and also of improving the effect in the recess left at the top. Sometimes a weathered or struck pointing is formed by pressing the lower line inside the joint. This has the advantage of not allowing the rain water to accumulate in the V-recess.

(iii) *Recessed Pointing*—See Fig. 587. The face of the pointing is pressed behind the plane of the wall and is left vertical instead of being made inclined.

(iv) *Keyed or Grooved Pointing*—See Figs. 588 and 589. The flat or flush pointing mentioned above is given an additional finish by lines or keyed grooves formed by pressing a special tool called *Naila.* It is claimed that this effect produces an improved appearance from a distance by creating artificial shady lines, specially in the case of brick masonry work. Grooved pointing has a bigger groove on the face than the keyed pointing.



Figs. 585 to 592. Showing different methods of pointing.

(v) *Tuck Pointing*—See Fig. 590. This consists of cutting a narrow channel or groove in the mortar after it is pressed into the joint. The groove is then filled in with white lime putty, which is left to project beyond the face of the joint by $\frac{1}{8}$ inch.

(vi) *V-Pointing*—There are two type of V-pointing; one is formed by projecting the V-shape of the pointing face outside the wall face, and the other by pressing the V-inside, as shown in Figs. 591 and 592 respectively.

Art. 241. Plastering General—Plastering is the term applied to the thin covering given to the surfaces of walls and ceilings. Sometimes the term rendering is used to indicate the finishing of the enterior work with cement or lime mortar or any coarse stuff. The purpose of plastering is primarily to cover up the irregularities of the surface of a wall and to hide the surface of the actual structure. The interior work can be preserved by a continuous rendering coat of plaster with a material possessing weather-proof qualities. In addition, plastering offers a neat and tidy appearance of a wall and thus has a great asthetical importance. Any desired decorative effect such as white or colour wash, distemper or paint can be had on plastered surfaces. But under no circumstances it should be the intention in plastering to hide bad workmanship and inferior materials.

Plaster may be applied directly to masonry such as stone, brick, concrete block, without the ground work of furring as explained in Art. 75. But the ground work of mortar required in this connection is explained later.

Mortar for Plastring–The mortar required for plastering is the same as that used for pointing. The lime used should be well screened so as to remove all unburnt and unslaked particles which in course of time will absorb moisture and cause "Blowing" by forming bristers, which results in the formation of cracks and peeling of plaster. For this purpose hydraulic lime is not very much recommended. Fat or rich lime with little hydraulic properties gives best results. Sometimes for external work lime mortar is gauged by adding cement in the ratio of 1: 6. To improve the binding properties of mortar for plaster work *gugal* (Amyres agallocha) at 10 lbs. per 100 cu. ft. of mortar is added when the mortar is being ground. A solution of *gur* (jaggery) at ¼ lb. to a gallon of water may also be added to the mortar when it is worked for proper consistancy before plastering. The use of fibrous material such as cattle hair and coconut or vegetable fibre is

also recommended for being added to the mortar to improve its adhesive and tensile properties, which are specially required for the first and second coats.

Art. 242. Method of Plastering–(*a*) *Preparation of surface*—As an initial measure every precaution must be taken to increase the adhesion between the plaster and the wall before the former is applied. For this purpose the joints and the surfaces of the masonry, etc. should be brushed clean, with a wire brush and should be free from oil, greese or soot. The projections and the bushing if any, which may interfere with the normal thickness of the plaster should be knocked off so as to present a general uniform surface of the wall. Similarly any low place should be also filled up in advance. The surface should then be freely wetted with water so as to clean the wall and keep it wet when the first coat of plaster is applied.

(*a*) *Plaster Ground Work*—The thickness of plaster is regulated by providing grounds or plaster levels on the wall surface. The wall is divided into vertical bays each bay being marked by dots or depth gauges. These dots are connected vertically by a continuous strip of plaster about 3″ wide and extending from the top of the wall to the bottom. Careful plumbing should be done in fixing the above dots. These narrow strips of plaster properly plumed and lined-up are termed as screeds and the operation is known screeding. The general surface of the plaster can be checked by stretching mason's string diagonally from corner to corner, This forms the groundwork for the application of plaster, the first coat of which can now be taken up. Stone masonry requires a thickness of ¾″ for plaster whereas for brick masonry only ½″ is enough.

(*c*) *Plaster Coat*—Plaster is applied in three coats. The first one is called the *rough course* the purpose of which is to cover up all the inequalities of the wall surface and is generally applied by dashing the mortar against the wall

surface in a layer of $\frac{3}{8}''$ thick between the plaster grounds mentioned above. This coat should be left exposed for 3 or 4 days for the mortar to harden. Its surface is left rough for the second coat called the *floating coat* to adhere to. The thickness of this floating coat is just $\frac{1}{4}''$ to $\frac{3}{8}''$. The final coat or the finishing coat which is usually of cream of lime or neeru is applied so as to give a smooth finishing surface of about $\frac{1}{8}''$ thick. The cream of lime is obtained by slaking fat lime or sea cells, the previous night in a tub or any container and by removing the next day morning the cream from the top, the extra water having been removed from the top of the tub. This cream is then deposited on sand beds, to further reduce its water content and to import it proper consistency to work with the mason's trowel. Neeru should be rubbed well with a trowel against the floating coat so as to develop a smooth finished surface.

In the case of plastering concrete face work hacking has to be resorted to for imparting a rough texture so that proper adhesion can be developed between it and the coat of plaster. This is also necessary in the case of brickwork, if it does not represent a rough textured face. It may be remarked that in general the success of a plaster work depends upon the skill and experience of the tradesman.

Lath and Plaster

Art. 243. Use of Lath in Plaster—Reference to this has already been made at the end of chap. VIII, Arts. 83 and 84. In modern practice the interiors of buildings are finished with lath and plaster. The use of lath is intended to offer a foundation to plaster and acts as reinforcement to the plaster of walls and ceilings. Any lath which has to be recommended for use with plaster to reinforce it should be judged by its ability to admit plaster to cling to it. Principally there are two types of laths, wood lath and metal lath, but only metal lath should be used for fire resisting construction.

Wood Lath—This is very commonly used for plastering the sides of timber partitions and celings of timber floors. Wood laths consist of strips of specially selected good seasoned wood, usually of the size 3' to 4' length and $1'' \times \frac{1}{2}''$ to $1'' \times \frac{3}{8}''$ in section. The lathing work consists in nailing these laths in parallel lines on the surfaces to be plastered so as to form a ground work for plaster. They are driven at a spacing of $\frac{3}{8}''$ apart and should break joint in alternate layers. The lath should be wetted thoroughly before the plaster is applied.

Metal Lath–This is available as already stated in different patterns such as expanded metal, woven wire, B. R. C. fabric Hy-Rib, self-centering, trussit, and forms a successful plaster base. The sheets of metal lath are attached by $1\frac{1}{4}''$–14 gauge wire nails spaced at 6″ to 9″ apart. Principally metal lath is available in the form of—

(*a*) Oven wire known as fabric or wire lath.

(*b*) Expanded metal lath formed of plane punched and expanded metal sheets.

(*c*) Expanded metal lath same as in (*b*) but stiffened by ribs and corrugations.

After the wood or metal lath is fixed the plastering work is carried out in the usual manner in different coats as already described.

Art. 244. Plaster Boards—Plaster boards of various kinds are also used to act as lath for plaster. These boards are porous and fibrous in texture and are fixed to masonry and concrete surfaces on a ground work of teak wood furring. See Art. 84 page 117. The details of furring are given in Fig. 190. This ground work of furring is nof necessary when plaster boards have to be fixed to teak wood joists, rafters or studs of timber partitions. Plaster boards are composed of cores of gypsum, surfaced with absorbant fibrous paper. They may be also of matted fibrous boards. At the corners strips of metal lath are used overlapping the joints.

Art. 245. Special Finishing to Plaster Surface— *(a) Special Compounds Used in Plastering*–In addition to the limes and cement, mentioned in the previous articles commonly used under ordinary condition of plastering work special compounds are are also added to produce the desired results such as hard plasters, acoustic plasters, asbestos marble plasters and plasters having fire resisting properties, These are mainly proprietory materials and are used in many cases for the finishing coat. A special mention of knee's cement made from gypsum may be made in this case. It offers a hard smooth finish and can be highly polished.Knee's cement is applied in three coats and where extensive areas are to be covered lime putty should be added to give sufficient time for proper finisning.

Sometimes coloured pigments are added to plasters to produce the desired decorative colour effects. The common mineral pigments are iron ore for red of buff, chromium for green, cobalt for blue. It is essential that these pigments should be ground very fine and uniformly mixed with plaster. Great skill and experience is necessary to handle these pigments and to produce desired effect, as mentioned above.

(b) Rough Finishing to Plastered Surface—The use of fine and coarse sand, gravel of different sizes, pebbles and pieces of flint is also very common to produce a rough effect on plastered surfaces. Depending upon the sizes of these particles we have a variety of plasters, varying from simple sand face plaster, smooth and rough cast plaster, to pebble dash and depter plasters. These are essential for external finishing of wall surfaces. The following is a brief description of carrylng out this type of work.

Sand Finish Plaster—To obtain the effect of a sanded surface, the final coat is finished by rubbing clean coarse sand with the aid of a wooden float. Lime plasters when green receive this sand surface very nicely and reprent a unifom yellow shade.

Pebble-dash—To obtain this effect the wall surface is given a rendering coat of coarse sand and cement, 1 : 3 ratio about $\frac{3}{8}''$ to $\frac{5}{8}''$ thick and against this, cleaned and washed pebbles of the disired size are dashed by means of a scoop. By using pieces of gravel or flint of different colours and pressing them by hand an ornamental effect can also be produced. This variety of rough-cast is termed as depter. The coare sand, gravel or pebbles in the above case may be covered by a wash of cement mixed with water proofing compound. Depending upon the size ofthese particles the plaster can be termed as rough-cast or smooth-castplaster.

(c) *Stucco*—This term is applied to external rendering specially intended to imitate stone or marble faces. The surface may be smooth and trowelled or left rough. Lime is used with sand of different sizes to produce the above types of surfaces. Before stucco is applied the surface should be prepared by applying the first two coats of plaster and if necessary a metal lath should be used.

CHAPTER XIX

Thermal Insulation and Fire Rsistance

Meaning of the terms:-Thermal Insulation. fire-resistnnce. Principles of thermal insulation. Individual and Total thermal resistance. Illustrative problem. Heat insulation methods and materials. Fire resistance construction. Common types used.

Art. 246. Meaning of the Terms—(a) Thermal Insulation-Heat is lost from a building in the following ways:

(a) By transmission through windows, doors and ventilators.

(b) By transmission through walls, floors and roofs.

(c) By air infiltration or inter-change throngh cracks, openings, etc. Conduction, convection and radiation are the three principal ways in which heat is transmitted or conveyed from one body or place to the other.

It is essential for a comfortable living that this transfurance of heat should be properly controlled so that the temperature inside the rooms of building should be maintrined at a suitable value. This required the transmission of heat throughthewalls, roofs, floors and such other structural members, to be brought down to a minimum in cold and hot weathers. The various materials to be used for construction should therefore have a very low conductive or a high theremal insulating value. Modern practice of building design gives more attention for the insulation of buildings, against heat losses, specially when the panel walls of framed structure are employed. Thermal insulation is also required in cold storage rooms, air conditioning installations. etc. It should be noted that what is true for heat installation is also true for insulation against cold. In the later case, is prevented from going out.

(b) Fire Resistance:—Buildings are also required to

be protected against the outbreaks of fire. Sometimes the term fireproof is used to indicate the property of fire resistance. The various part of building such as walls, floors and roofs, doors and windows, columns and beams, stair-cases, etc. should be designed and built of materials which exhibit adequate fire preventing and fire resisting properties. Buildings are therefore classified according to the type of constructions such as:—

(i) Fire proof; (ii) Semi-Fire-proof; and
(iii) Ordinary construction.

For a fire proof construction, the various parts of the bulding should at least resist the effects of fiire for about four hours. This is reduced to two hours in the case of semi-fire-proof constructions. Standard fire tests are carried out for different materials to determine their ability to withstand the heat load and they are graded as A,B,C,D,&E, in accordance as the length of time they resist effects of fire in hours.viz.6, 4, 2, 1 & ½ respectively. The general idea implied is that, in a fire resisting construction sufficient time is givenfrom the commencement of theconfligeration,to employ satisfactory and adequate measures to extinguish fire without muchdamageand also to allow enough time for the automatic devices like sprinklers and drenchers to come into operation.

Art. 247. Principles of Thermal Insulations—The conductivity K of a material is the amount of heat in B.T.U. which will flow in one hour through a layer of that material, having one square foot in area and one inch thickness, when the temperature is 1° F between the two surfaces of the layer Each materialhas its own value for K. Theresistivityor thermal resistance is the reciprocal of conductivity i. e. 1/K per square inch thickness of the insulating material. The total insulating value of a layer of material of thickness T inches, or the thermal resistance is obtained by dividing T by K. Thus we have, Thermal Resistance $R = \frac{\text{Thickness of Layer, T}}{\text{Conductivity, K}}$

and thermal Transmittance, $U = 1/R$.

The above relations are true for any one material or a combination of two or more layers of different materials put together. Thus the combined thermal resistance of a composite medium is equal to the sum of the thermal resistance of each one and from which the U–value of the whole media is worked out.

Art. 248. Total Thermal Resistance of Media— While desingning a structure for heat insulation, thermal resistance, is always specified in the from of U–value, and from the known thermal conductivity of an insulating material, a suitable insulating media could be conveniently designed.

In addition to the thermal insulation value of the materials proper, which generally includes the walls only but not the plaster, heat tranmission could also be reduced by providing air spaces. This requires the design of walls to include a cavity in their thickness. But a thickness of more than $\frac{1}{4}$ inch of air space generally sets in convection currents and the insulation is affected.

In addition to the above three types of thermel resistances viz. the wall. the plaster and air space, there is also a resistance to heat flowexhibited by the surface of the matarial exposed to air. The surface of a plastered wall exposed to the outside air or the inside air of a room has a film resistance of about 0.3, while that of the surface exposed to still air or air locked up in the interspace could be taken at a lower value of upto 0.2.

When a thermal insulating material is used, it will also add to the total thermal resistance of the media. Thus the total thermal resistance R of a media is given by:—

$R = F + W + P + A + I$, where

F = Film resistance of air exposed surfaces.

W = Thermal resistance of bare wall.

p = Thermal resistance of plastered finishes.

A = Thermal resistance due to air space.

I = Thermal resistance of the insulating material used, from which we get $U = 1/R$ as already explained.

For normal dwelling houses, a minimum thermal transmitance or U–Value of 0.3 to 0.35 is generally recommended. This is brought down to 0.25 or so when good comfortable conditions are desired at a slightly increased cost. But for special work where insulation is the main problem and has an industrial importance, values of U as low as 0.1 to 0.15 are not uncommon.

The following are the typical approximate values for heat transmission and thermal resistance coeffcients pre inch thickness.

TABLE No. XIV

Thermal Resistance Coefficients.

S. No.	Materials	Heat Transmission Co-efficient	Thermal Resistance Co-efficient
1	Stone masonry ...	10.00	0.10
2	Brick Masonry ...	6.70	0.15
3	Concrete	10.00	0.10
4	Cement plaster ...	10.00	0.10
5	Hollow Block brick masonry	4.00	0.25
6	Ordinary wood ...	0.75	1.33
7	Flexible blankets, felts and quilts. ...	0.25	4.00
8	Fibre Boards ...	0.34	3.00
6	Saw Dust and wood shavings	4.00	0.25
10	Insulating Plaster ...	4.00	0.25

Art. 249. Illustrative Problem—A 9-in. brick masonry wall with $\frac{3}{4}''$ plaster on both the faces has a thermal transmission or U value of about 0.45. It is required to reduce this U value to 0.3 for comfortable inside living conditions. Fibre board has a resistivity of 3.0 or a thermal conductivity of 0.34. It is proposed to fix this on the inside of the wall with an air gap of 0.75 inch. Thus we have total thermal resistivity given by :—

Outside plastered surface fim resistance. $F_1 = 0.30$
Interpace plastered surface film resistance, $F_2 = 0.20$

Hence we have .. ... $F = 0.50$

$9''$ brick masonrysolid wall thermal resistance

$W = 1.35 \times 9 = 1.35$

2 layer of $\frac{3}{4}''$ in. Plaster $= 0.075 \times 2$ ... $P = 0.15$

Thermal resistance of $\frac{3}{4}''$ in. air space, $A = 0.75$

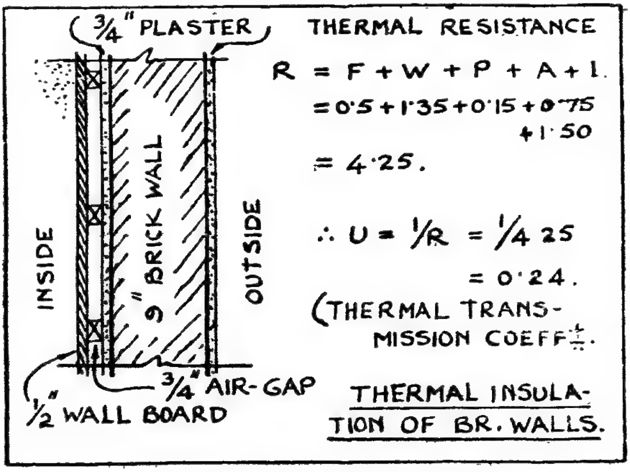


Fig: Thermal insulstion walls.

Thermal resistance of $\frac{1}{8}''$ in. wallboard, $I = 1.50$

Therefore, $R = F + W + P + A + I$

$= 0.50 + 1.35 + 0.15 + 0.75 + 1.50$

$= 4.25$

Thermal transmission, U value $= \frac{1}{4.25} = 0.24$

Similary a 6—in. concrete wall with an internal lining of $\frac{1}{2}''$ thick fibre board on $\frac{3}{4}''$ battens has a U value of 0.2 to 0.25 against a value of 0.5 withont any installation for heat insulation.

Heat transmission coefficient values of various standard materials of construction and also those of proprietory product of thermal insulation, advice is to be sought of firms which manufacture these products.

Art. 250. Heat Insulation, Materials and Methods— The common materials used for insulation have low density, porous and fibrous texture, low conductivity or high resistance to the transmission of heat. Their insulation property is mainly due to the minute air spaces throghout heir body. Iusulating materials are also of the reflective type, The effectiveness of these materials is due to their reflecting of

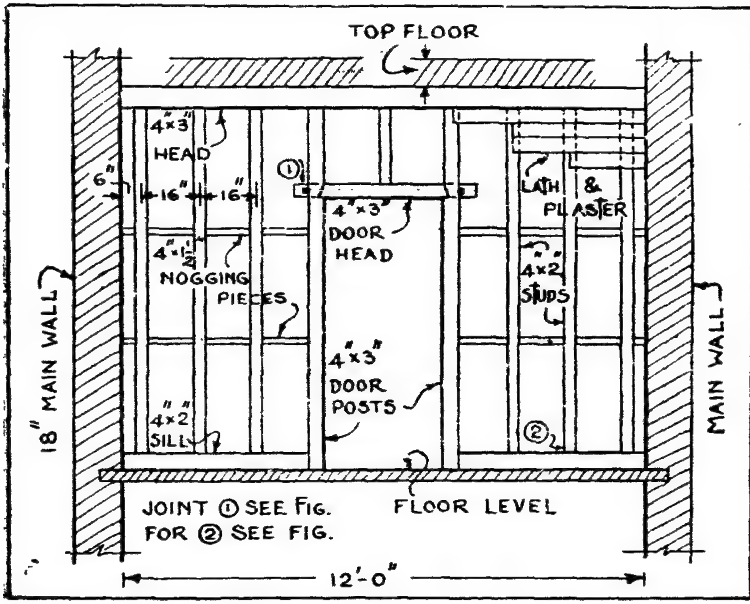


Fig. 593. Ordinary teak wood partition to be covered with nccessary heat insulating materials.

the radiant energy from their surface. The following are the common methods of heat insulation adopted;

(i) *Rigid or Semi-Rigid Insulation.* Wall boards, compressed hard boards and fibre boards are used for interior lining of walls and roofs. A frame work of wooden battens is fixed to the wall surface by means of T. W. plugs. Consequently an air sqace of ½" to ¼" could be formed between the wall and the board or roof. The circulation of air currents should

be prevented in this air space. This is termed as Rigid or Semi-Rigid heat insulation. These boards could be used also to form a light partition by using wooden or metal studs. Conduction value of 0.3 to 0.4 is generally obtained by this. In the case of combustive type of wall boards special treatment like the application of fire resisting paints or solutions

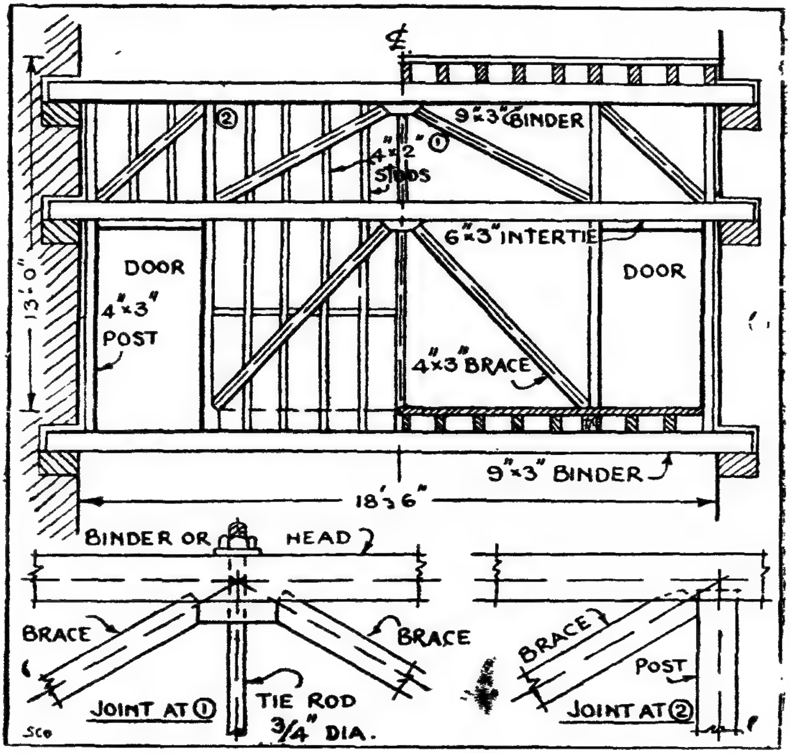


Fig. 594 to 596. Framed teak wood stud partiion work. Ready for applying desired insulating materials.

should be given. Cork in the form of slabs 1"to ½' thick is very effectively used for thermal insulation. Their conductivity is as low as 0.3to0.4. Rigid insulation is recommended for parts of building which have to bear loads. See Figs. 593 to 596.

(ii) *Flexible Insulation*-In this type of insulation flexible materials are used, such as blankets, quilts, felts, etc. which

are manufactured of fibrous materials. These materials are wood fibres, jute fibres, flax fibres, mineral or rock wool, glasswool, ell glass, fomed slag, etc. The material is in the form of rolls and is spread on the surface of walls and ceilings. Flexible insulation is recommended for structural members which do not bear loads. In Fig. 597 heat insulation of sloped roofs is shown.

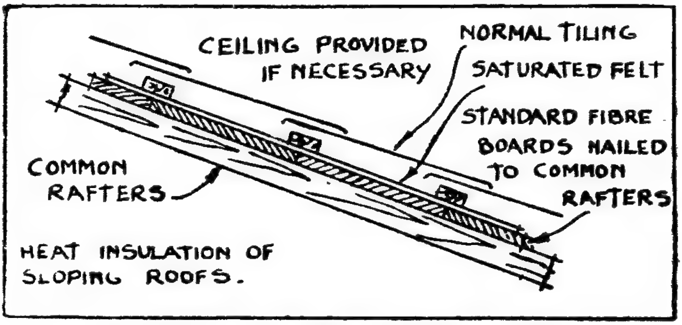


Fig. 597. Heat insulation of sloping roofs.

(iii). *Fill Insulation*—Heat insulation can also be had by filling granulated materials like cork, rock wool, or fibrous materials like mineral wool, glass wool, into the hollow space between the wall studs and wall boards, ceilings and boarding, etc. This is often carried out in addition to the first two mentioned above.

(iv) **Reflective Insulation**—This type ot insulation is used in air spaces, between the studs, joists, rafters, etc. Its effectiveness is mainly due to the reflecting of radiant energy reaching the surface. This requires the surface of the heat insulating material to be bright and clean. The common materials used for this purpose are alluminium paper alluminium foil, thin sheets of alluminium, copper and tin.

Art. 251. Fire Resistance Construction–The materials used in such construction, should possess fire resisting and fire preventing qualities of the desired standard. Under the effect of heat developed during the occurance of fire, they should not show any tendency to buldge, buckle and collapse.

The nature of occupancy, viz. industrial, office, residential or otherwise should be kept in view while designing fire resisting costruction. The cost of construction is very often sacrificed to secure maximom safety of the stored materials and occupants, and the best type of construction proportionately suitable is recommended in each case.

Sufficient number of openings should be provided in the walls for doors and windows, But in the case of walled structure if this area is more than 25 to 30%, a proportionate increase of 2 to 4 ins. should be allowed, in the wall thickness.

Materials used—Stone disintegrates under the effect of heating and cooling; but sandstones are better than granite or limestone. Bricks in general are quite suitable for fire resisting construction, though special bricks of fire clay materials and terra cotta are sometimes recommended. Metals in general are not suitable as they buckle when suddenly cooled down by the application of water during the period of configeration, after they once get heated. Cast iron, wrought iron and steel columns and beams require to be encased by terracotta or fire clay bricks or by lath and fire proof plaster. Concrete is a very good material to resist fire. The use of broken brick, furnace slag, coke breeze, as material for aggregate is often recommended in preferance to broken stone for fire resisting purposes. Timber in heavy sections can be trusted to resist fire, as once the surface is charred, it prevents the further attack by fire. However fire proof paints of standard manufacture should be used to cover the surface of timber members or any member, in a building. On ignition they give out gases which retard combustion. Good may types of fire resisting plasters and paints of proprietory products are now available in the markets. The use of asbestos fibres in plasters develops better fire resisting properties in them.

Art. 252. Automatic Sprinklers—In modern practice automatic water sprinklers are installed inside a building at suitable location. To feed these sprinklers there must be a provision for an independant tank on the roof or a seperate

elevated tower. The nozzles of the sprinklers are closed by fusible plugs which melt at a higher temperature when a fire occurs and the spray then comes into operation. Suitable water supply mains and distribution pipes are laid all over the place and nozzles are provided to obtain a spray of water.

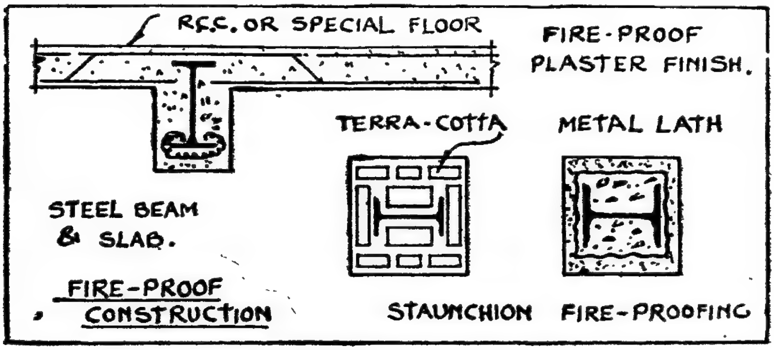


Fig. 598. Fire Proof contruction.

Art. 253. Common types of Fire Resisting Construction—In the following fig. 598 some common types of fire resisting constructions are shown. See also the methods of construction shown in Chapters VII and XIII, for walls and floors.

CHAPTER XVI

Sound Insulation

Preliminary remarks-Sound insulation and acoustics. Transmission of noise. Airborne. structure borne and impact noise. Noise due to machinery. Sound Insulating materials. Sound absorbant coefficieints. Acoustical defects-Insufficient Loudness, echo formation Reverberation. Sound foci. Insufficient Intensity. Transference. Interference.

Art. 254. Preliminary Remarks—In modern practice of building design and construction much importance is given to sound insulation and improvement of acoustical conditions with a view to exclude and deaden the noise and the consequent disturbances. Good acoustical conditions promote comfortable living, efficiency of work, auditory of public buildings, etc. This requires the following two problems to be considered.

(1) To control the disturbances due to noise i. e. *Sound Insulation.*

(2) To control and remedy the acoustical defects i. e. *Acoustics.*

In the following articles, the various aspects of these two problems and the methods adopted in the design and construction of the building together with the materials used are discussed.

Measurement of Sound—Sound is transmitted by wave motion and we hear due to the pressure fluctuations or pressure impulses, produced by a sound, reaching our ears. The impulses of pressure are expressed by their frequency or by the number of cycles per second, a louder sound having a higher frequency. The unit of measurement of loudness of a voice is termed as phon and is used for solving practical problems of sound insulation and acoustics. The phon scale extends from 0 to 130 and each sound is valued as so many

phons in the scale. In sound insulation, attempt is made to reduce the number of phons to the required value. The phon value as required in a room is different in each case. A radio set produces a loudness of 80 phons and if it is required that in a neighbouring study room a quiet condition of 25 phons has to be maintained. The problem is to design the walls etc., of this study room in such a manner that there is a reduction of 55 phons in the transmission of the radio noise to inside the study room. In special cases where a considerable reduction in phons is necessary as in the case of excluding the noise of suburban trains, traffic in a busy street, etc., for quiet working condition in offices, study and living rooms, special sound insulation methods have to be adopted. Quiet conditions prevail in a room if the loudness value of noise in it is about 20 phons or less; aeroplane noise has a phon value of about 120. It should be noted that if there are two sources of noise in a room, one having a loudness value of 35 phons and the other of 70 phons, the room will not have a noise of loudness of 105 phons. Because the louder noise deadens the effect to the noise having a lesser phon value. This indicates that the phon values of different sounds are not additive. Phon value for any noise is determined by noise meters.

A standard tone is considered to have a frequency of 1000 cycles persecond,and the loudness of a noise is compared with it by hearing. This requires trained observers. In another case the noise meter measures the energy of a source of a noise, A micro-phone converts the sound energy into electrical energy which is registered as on a meter, on which the phons could be read directly. *Decible* is also used to express the change in the energy of a sound wave. The ratio of the change in the sound energy of 1 to 1000 corresponds to a decible value of 3 which is the logaritham number of the ratio of this energy change. The decible valve is taken as equivalent to the phon value.

Art. 255. Transmission of Noise—Noise is transmitted in three ways:—

(1) Through the air.

(2) By the vibration of the structural members.

(3) Through tha structural members.

It is a simple thing to realise that sound is transmitted through the air, and through the openings in walls, cracks, etc., the sound waves get a passage and reach the inside of a room. Some of the sound waves impunge on thin partitions and membrane walls which vibrate on their turn and again set up the sound waves on the other side and thus transmit the sound. Sound waves also set up flexural movements in

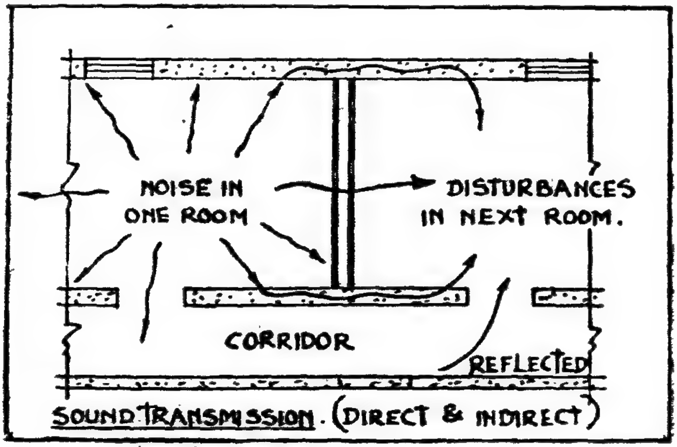


Fig. 599. Transmission of sound.

wall and the pressure impulses are conveyed through it to come out on the opposite side to start again as sound waves in the air. These three methods of sound transmission are illustrated in fig. 599.

Art. 256. Sound Insulation—For the purpose of solving problems of sound insulation, the noises to be handled are broadly divided into—

(i) Air borne noise;

(ii) Structure borne noise;

(iii) Impact noiee

Another classification is—

(i) Outdoor noise; and (ii) Indoor noise.

The amount of noise reduction to be secured by any sound insulation sy stem depends mainly upon the sense of the occupants. In a countryside the loudness of a noise should be round about 15 to 20 phons, while in a public building located in a basy street, the loudness of noise could be kept at a much higher standard of 45 to 55 phons. As an initial precaution, to exclude the noise, the building should be located as far away from the source of noise as possible. It should be preferably guarded by trees.

As a first step, *the opening of the walls* should be minimum. Windows, ventilators, doors and such other openings in the wall reduce the insulating value of that wall so much, that if they occupy about one third the area, the wall having the same has no insulating value. It may be taken that ordinary glass if used in a window, has a noise reduction values of about 25 phons.

Lightness and thickness are against sound insulation while weight increases it. Thickness of wall has an increased phon reduction value, but not in the same ratio. For examble the reduction value of phons obtainable by using $4\frac{1}{2}''$, $9''$ and $13\frac{1}{2}''$ brick masonry walls are about 45, 50 and 55 respectively. Cavity walls are more effective than solid ones. Double shutters for doors and windows with an air gap in between are very effective in securing sound insulation. *Walled Structures* are verp effective for securing sound insulation while framed structures are quite favourable for the transmission of structure borne and impact noise. Therefore the best type of sound insulation is always possible in a discontinuous construction. The various structural members are kept discontinuous and independent by the use of flexible and resilient materials at their junctions. But a fully discontinuous constrution is very costly. Similarly floating floors and suspended cellings are rccommended for reducing the structure borne

noise. But these are only used where sound insulation is the main factor in construction. In this case flexible paddings are used as cushions at all points, where the floor rests on walls or on the frame work of the building.

Noise due to the Machinery—Machine foundations should be isolated from the main structure by introducing flexible and resilient materials like springs, felt, cork, rubber, canvas etc. But the thickness of this padding should be very carefully fixed as otherwise if more padding is used as compared to the weight of the machinery coming upon it, vibrations are increased and the purpose will not be served. Structure borne noise and the noise due to vibrations and impact noise is much more idfficult to handle than the air borne noise. For reducing the air borne noise also from the machinery, proper lining for the walls, floors and ceiling of the room, where machinery is located, with sound absorbant medium should be provided. For supporting machinery on the upper floors, floating floors are found to be more effective. But they are expensive.

Art. .257. Sound Insulating Materials—The inner surface of walls and roof. Should be provided with sound asborbant linings with air spaces. Many standard proprietory materials are now used in the market and they claim sound insulation as one of their characteristic property. In fact, the properties of heat and shound insulation go generally hand in hand and in designing, both these requirements are kept in view side by side. These wall linings act more as sound absorbant media and reduce the general level of the sound in a room, rather than acting as sound insulating media. They reduce the reflection and reverberation of sound. Their effectiveness is mainly due to cavities in them and the air in these cavities acts as cushions and absorb the sound energy.

Plasters for covering walls and ceilings, with rough finished surface are invariably recommended, for sound absorption, since their rough surface is not good for reflecting the sound waves. Their sound absorbant value is proportional to the roughness of their surface. Paint-

ing the rough surface of a sound insulating material reduces their effectiveness.

A stud partition cavity wall with fibre boards or lath and plaster on both the sides is more effective if its cavity is filled with some fibrous or puffing material;see Fig.600 and also the figures given in Arts. 83, 84 and 148. Concrete walls offer resistance to sound but when they are reinforced with steel bars they transmit structure borne sound very easily.

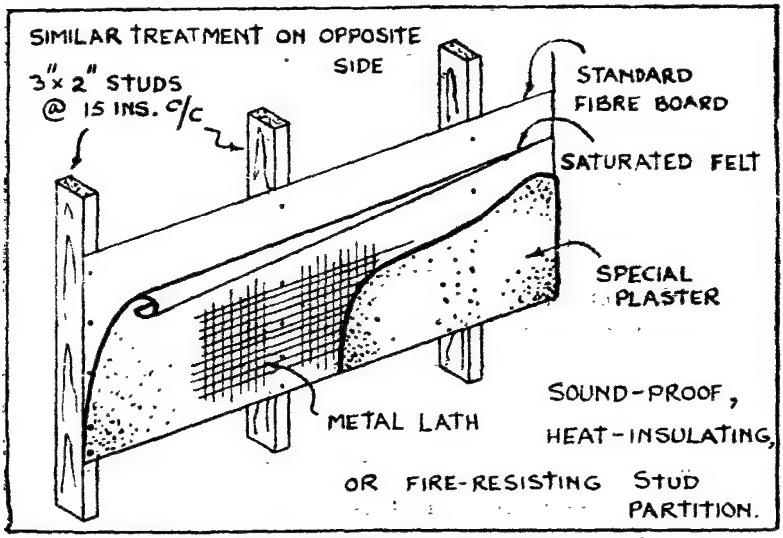


Fig. 600. Insulation of a Stud partition.

Art. 258. Sound Absorbant Coefficients—For the purpose of comparing the sound absorption of various materials,the absorption of an open window is considered as 100 per cent or absorption coefficient of an open window is taken as 1, so far as no sound is reflected back into the room. This should not be confused with the transmission of sound which does not take place through an open window. If we now place across this window opening, a barrier say of cork board, it will absorb only 0.35 of the sound energy and reflect back 0.65 of the same energy striking it. A felt will have an absorbant cofficient of 0.5. Similarly the sound absorption comparative coefficients are worked for acoustical problems.

As sound absorption coefficients vary with the frequency, a value of 512 cycles per second is taken as that for medium sounds for expressing these coefficients. The approximate values of these coefficients of different materials are given below for the purpose of studying varying acoustical aspects—

1.	Open window	1.00
2.	Unplastered brick or stone masonry rough wall	0.05
3.	Smooth finish plaster	0.02
4.	Rough finish plaster	0.02
5.	Acoustical materials, upto	0.50

The total absorption by the walls, roofs, and floor surfaces by the occupants and by the articles placed inside a room are calculated for finding out the sound reduction coefficients. This gives an idea about the bad or good acoustical effects inside a hall. The absorption units of a surface are expressed as the product of the area in feet and its absorption co-efficient. If a rough plastered wall surface has an area of 5600 sq.ft. and if its absorption coefficient is 0.07, then it absorbs $5600 \times 0.07 = 392$ units. If acoustical plaster is used, the sound absorption units work out to be $5600 \times 0.25 = 1400$ units. In this way the absorption units of untreated rooms are worked out and depending upon those required for developing necessary acoustical conditions inside a hall, a suitable acoustical treatment for the hall is recommended. Persons sitting inside an auditorium have a sound absorption of about 4 units each, while chairs are equivalent to 2 absorption units.

Art. 259. Acoustical Defects—The following are the various defects in the acoustics of a hall and they should be minimised as far as possible.

(a) *Insufficient Loudness*—The speakers' voice or music from stage should be sufficiently audible in all parts of the hall at a uniform intensity of loudness. This is very important in theatrical buildings and large auditoriums. This requires the sound waves to be properly reflected and

uniformly spread all over the interior. The stage should be preferably surrounded by sound reflecting flat surfaces rather than sound abosrbing curtains. Similarly deep balconies should be avoided as these will naturally have corresponding depth under balcony spaces. The depth of an under balcony space should not be more than 2½ to 3 times the front height leading to them. In large auditoriums direct sound is insufficient and has to be reinforced by loud speakers. Generally the length of a hall is limited to about 80 to 85 feet. If there is a very large number of window or door openings, the loudness of the sound becomes insufficient, and its audibility is rednced.

(b) *Echo Formation*–Sound is reflected from the surfaces of walls, roof and ceilings of rooms so that in addition to the direct hearing of a voice, there will also be an indirect or a reflected voice which is termed as an *Echo*, reaching the ear after some time. The energy of the reflected sound waves is dependent on the smoothness or otherwise of the surface they strike. Rough and porous surfaces reduce this reflected enery to a larger extent. This acoustical defect of echo formation is much more prominent in deep and high halls with bare smooth walls. Echoes cause disturbance and unpleasant hearing.

The formation of echos is avoided by scattering or dispersing the reflected sound energy and by properly proportioning the size of the hall. Several types of acoustical finishings for surfaces are available to produce this effect.

(c) *Reverberation*—It has been pointed above that the sound produced in a room is reflected on the surfaces of walls and ceiling, etc., and echoes are formed. But this reflection does not stop after it once takes place. The sound is reflected back and forth against the walls, ceiling and floors several times and these reflections continue several times even after the source has stopped producing the sound. If the surfaces of reflection are quite smooth so that no energy is lost after reflection the echoes will build up

maximum intensity which continues indefinitely. This prolongation of the sound after the source producing it, has ceased, is called *Reverberation.* As reverberation refers to the period of prolongation, it is measured quantitatively by the length of time reqired for sound to become inaudible after stopping the source. For the purpose of comparision a standard sound of 1000 frequency is generated and the effects on the formation of echoes and reverberation are studied.

If T is the reverberation time in seconds, V is the volume of the room in cubic feet, and A is the total of the absorption units in the room, we have,—

$$T = 0.05\ V/A \text{ Seconds.}$$

While calculating the total absorption units, the oocupants and the articles occupying the hall are all taken into account. For best hearing effects the reverberation time should be between 1 and 2 seconds, but it is tolerable if it goes upto 3 seconds. The hearing condition becomes definitely very poor if the reverberation time exceeds 3 seconds. Generally reverberation of sound is controlled by the use of acoustical materials having high absorption coefficient.

(*d*)*Sound Foci*—When sound is refiected from the interior surfaces of a hall, depending upon the curvature of these surfaces, there is a possibility for these reflected sound rays to meet at a point, called sound focus. This causes concentration effect for the reflected echoes and consequently the sound is heard unusually loud. Sound foci are formed specially with curved or domed ceilings. The curve of the ceiling should be exactly worked out geometrically and the most suitable shape to be determined accordingly. The other two aspects of acousties. viz. (1) *Intensity of Sound* quite suitable for producing the right type of loundness on the phone scale, and (2) the transferrance of sound both air borne and structure borne, have been already considered early this chapter.

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